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FURTHER INVESTIGATION INTO THE WATER QUALITY PARAMETERS USED IN THE LOWER KANSAS RIVER BASIN MODEL

Walter J. O'Brien, et al

Kansas University
Lawrence, Kansas

June 1968

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by

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and

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MISSOURI-SOURIS-RED RIVER BASINS COMPREHENSIVE
WATER POLLUTION CONTROL PROJECT

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Center for Research, Inc.
Engineering Science Division
Lawrence, Kansas

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Abstract

A modification of the discharge translation procedure used in the Lower Kansas River Quality Model is presented. The conservative water quality vectors used in the model have also been refined to produce improved correlation between the predicted and observed concentrations of chloride, sulfate, calcium, and magnesium as a function of the discharge in the river system.

A method for predicting the percentage composition and the concentration of conservative parameters in the reservoirs of the region from pre-impoundment water quality data is presented. The non-conservative and the temperature data available on the region are also summarized in a form suitable for use in the model.

Acknowledgement

The data used in preparing this report were obtained from the Kansas State Health Department, the Kansas Geological Survey, the appropriate Water Supply Papers of the U. S. Geological Survey and the field investigations of the Federal Water Pollution Control Administration. We have attempted to credit individual sources in the body of the report. However, we would like to take this opportunity to thank the members of these organizations who have been so generous of their time in our behalf.

The Lawrence District Office of the U. S. Geological Survey and the Kansas City District Office of the U. S. Corps of Engineers was most cooperative in furnishing information on river discharges and on discharge rating curves.

Mr. Paul MacRoberts developed the modified discharge translation procedure outlined in the report as part of a thesis submitted to the University of Kansas for the degree, Master of Science in Water Resources Engineering.

Mr. Euiso Choi, Mr. John Stahl, Mrs. Geraldine O'Brien, and Mrs. Diane Schwegler performed much of the computational and drafting work in the report.

The computations were performed on the facilities of the University of Kansas Computation Center.

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I. Introduction

The purpose of the research summarized in this report was to expand and further refine the conservative and the non-conservative water quality vectors used in the Lower Kansas River Basin Model. A modification of the discharge translation procedure has also been developed and is included in the report. The basic model has been described in detail in an earlier report (1).

The material contained in this report is believed to be more accurate than that presented in the publication outlining the development and operation of the Lower Kansas River Basin Model. The water quality vectors presented herein therefore supersede the earlier material in those instances where the numerical values differ. The two documents are, therefore, companion volumes and should be used in conjunction with each other.

The report consists of the following subdivisions:

1. A summary of the sampling network used in defining the water quality of the Lower Kansas River basin.
2. A description of the new discharge translation procedure and a discussion of the computer program developed for using this technique.
3. Four sets of conservative vectors for predicting the concentration of chloride, sulfate, calcium, and magnesium in the river network included in the model.

4. An outline of a technique for predicting the conservative water quality in Perry, Milford, Glen Elder, and Wilson Reservoirs from water quality measurements obtained before impoundment.
5. An analysis of the non-conservative water quality measurements obtained by the Kansas State Department of Health during 1966 and 1967.
6. A summary of the monthly variation in stream water temperature in the Lower Kansas River basin.
7. A series of modifications on the fixed vectors used in the model. These changes were, in part, based upon the time of flow measurements made by the Federal Water Pollution Control Administration and the Kansas State Department of Health.

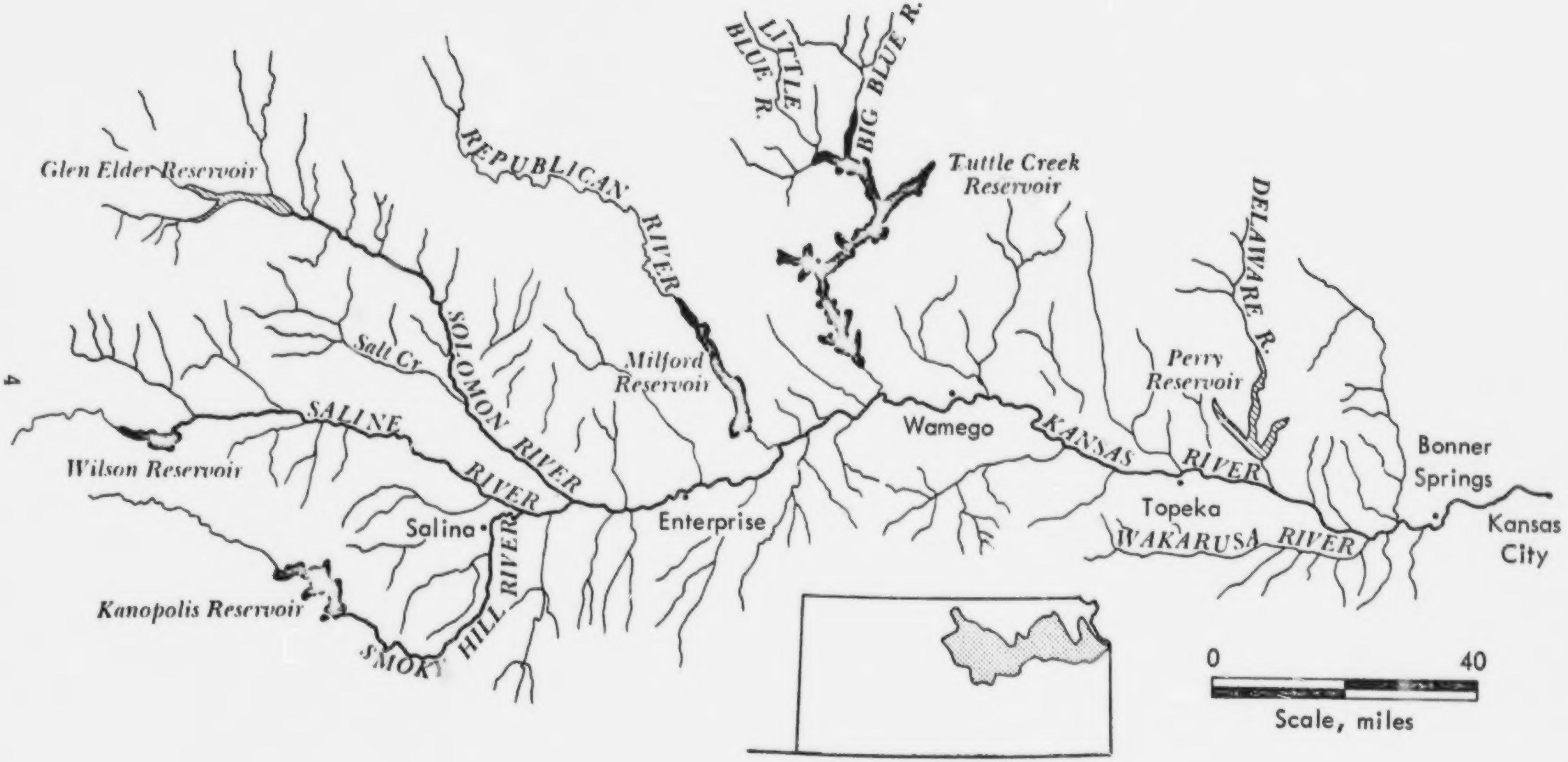
A summary of the areas which require additional research is also presented.

II. The Sampling Program

The portion of the Kansas River Basin included in the Lower Kansas River Model is illustrated in Figure 1. Comprehensive reviews of the geography, the hydrology, and the water resources problems of the region have been published previously (1), (2), (3) and (4).

The network of regular water-quality sampling stations operated jointly by the United States Geological Survey and the Kansas State Health Department, and the supplemental water-quality stations operated by the Kansas State Health Department from June, 1966 through May, 1967 are shown in Figure 2. A detailed description of the sites is given in Table 1. Chemical water quality data are available for all 28 stations. The chemical analyses for the supplemental stations operated from June through August, 1966 were performed by the Kansas Geological Survey and have been published in a previous report (5).

Selected chemical and biochemical analyses were performed by the Kansas State Health Department on the supplemental water-quality stations operated from June, 1966 through May, 1967. These analyses were used in preparing the non-conservative vectors presented in this report.


Glen Elder Reservoir
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BIG BLUE R.
Tuttle Creek Reservoir
DELAWARE R.
Salt Cr.
SOLOMON RIVER
Milford Reservoir
Perry Reservoir
Wilson Reservoir
SALINE RIVER
Wamego
KANSAS RIVER
Bonner Springs
Salina
Enterprise
Topeka
WAKARUSA RIVER
Kansas City
Kanopolis Reservoir
SMOKY HILL RIVER
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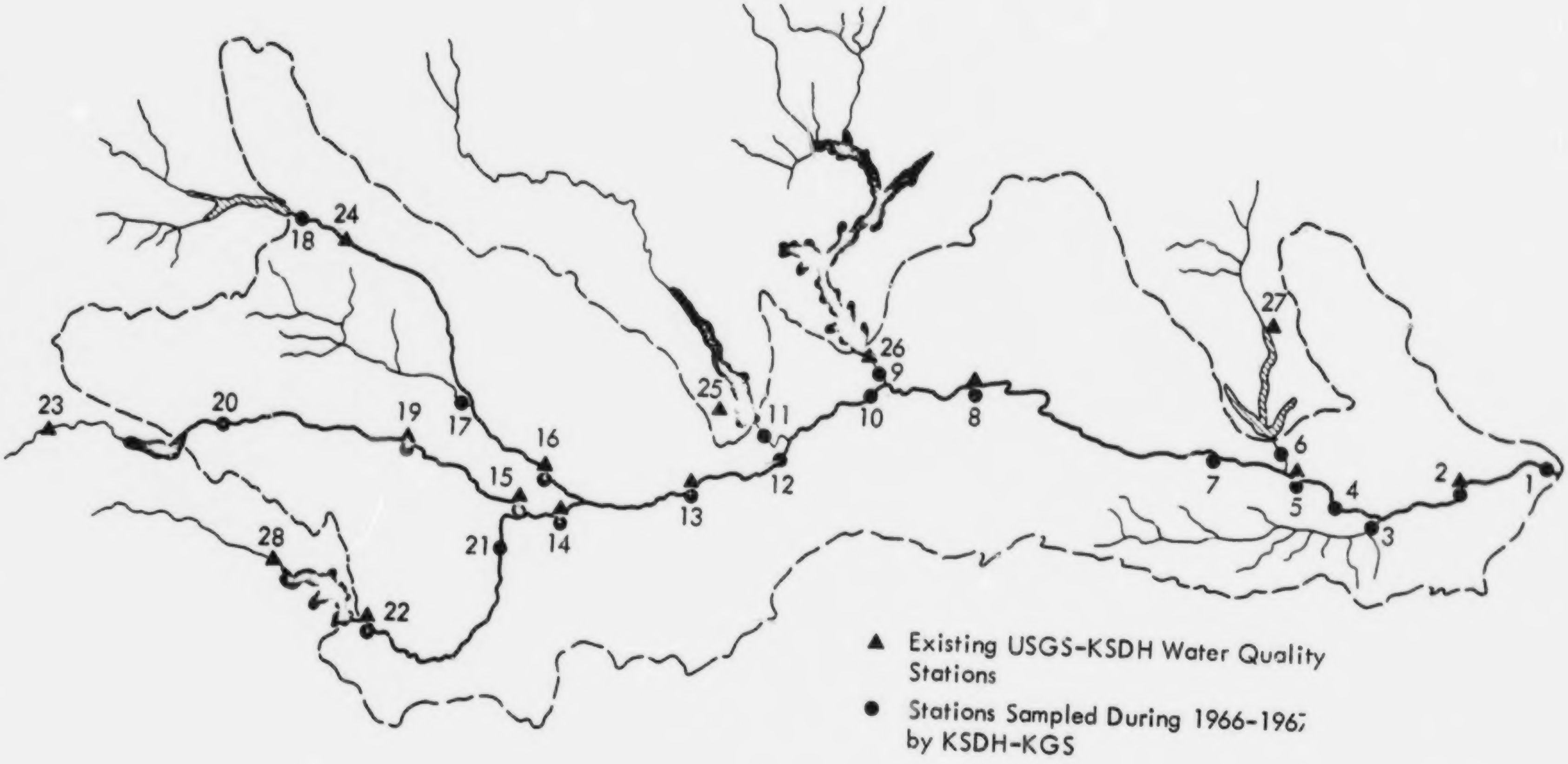
Scale, miles

Figure 1 Location Map and Physical Details of the Lower Kansas River Basin Model Area.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▲ Existing USGS-KSDH Water Quality Stations
● Stations Sampled During 1966-1967 by KSDH-KGS

Figure 2 Location Map of the Water Quality Sampling Stations Used in Developing the Lower Kansas River Basin Model

Table 1

Water Quality Stations Used in the Lower Kansas River Basin Model

No.	Station Name	Stream	River Mile	Period of Record	USGS Station No.
1	Kansas City	Kansas River	0.3	6/66 - 8/66	——
2	Bonner Springs	Kansas River	20.3	1961 - 1964 6/66 - 5/67	6-8923
3	Eudora	Wakarusa River	41.7-0.4	6/66 - 8/66	——
4	Lawrence	Kansas River	53.1	6/66 - 8/66	——
5	Lecompton	Kansas River	64.1	1957 - 1958 1961 - 1964 6/66 - 5/67	6-8910
6	Perry	Delaware River	64.7-1.8	6/66 - 8/66	——
7	Topeka	Kansas River	84.0	6/66 - 5/67	6-8890
8	Wamego	Kansas River	129.1	1956 - 1958 1961 - 1964 6/66 - 5/67	6-8875
9	Casement Bridge	Big Blue River	147.1-7.3	6/66 - 5/67	——
10	Manhattan	Kansas River	148.3	6/66 - 8/66	——
11	Milford	Republican River	170.4-6.0	6/66 - 5/67	——
12	Junction City	Smoky Hill River	170.4-2.0	6/66 - 8/66	——

Table 1 (Continued)

No.	Station Name	Stream	River Mile	Period of Record	USGS Station No.
13	Enterprise	Smoky Hill River	170.4-43.3	1955 - 1958 1961 - 1964 6/66 - 5/67	6-8776
14	New Cambria	Smoky Hill River	170.4-83.7	1962 - 1964 6/66 - 8/66	6-8776
15	New Cambria	Saline River	170.4-89.6-2.0	1962 - 1964 6/66 - 8/66	6-8769
16	Niles	Solomon River	170.4-68.3-16.9	1958 - 1964 6/66 - 8/66	6-8769
17	Minneapolis	Salt Creek	170.4-68.3-45.9-10.4	6/66 - 8/66	——
18	Glen Elder	Solomon River	170.4-68.3-155.1	6/66 - 5/67	——
19	Tescott	Saline River	170.4-89.6-68.5	1949 - 1953 1961 - 1964 6/66 - 8/66	6-8695
20	Sylvan Grove	Saline River	170.4-89.6-113.5	6/66 - 5/67	——
21	Mentor	Smoky Hill River	170.4-117.0	1963 - 1964 6/66 - 8/66	6-8665
22	Langley	Smoky Hill River	170.4-177.0	1961 - 1964 6/66 - 5/67	6-8655
23	Russell	Saline River	170.4-89.6-167.9	1946 - 1949 1961 - 1964	6-8670

Table 1 (Continued)

No.	Station Name	Stream	River Mile	Period of Record	USGS Station No.
24	Beloit	Solomon River	170.4-68.3-130.6	1949 - 1952 1957 - 1958 1959 - 1964	6-8760
25	Milford	Republican River	170.4-18.6	1955 - 1958 1961 - 1964	6-8570
26	Manhattan	Big Blue River	147.1-9.7	1955 - 1958 1961 - 1964	6-8870
27	Valley Falls	Delaware River	64.7-30.6	1961 - 1964	6-8905
28	Ellsworth	Smoky Hill River	170.4-207.8	1957 - 1959 1961 - 1964	6-8645

III. Modification of the Discharge Translation Procedure

The lower Kansas River Basin differs from more complex hydrologically orientated hydrograph reconstitution models in that it utilizes a discharge translation process for the development of hydrographs between conservative river gages. This approach was adopted during the initial stages of development in order to satisfy two fundamental conditions. These are:

1. The model must be easily adaptable to other mid-western basins.
2. The model must be orientated toward water quality rather than hydrology.

It was, therefore, decided that the hydrologic and hydraulic refinements which can be achieved from more sophisticated routing models were not warranted.

Pollution problems are most prevalent in the normal ranges of discharges. During periods of flooding, water quality considerations are overlooked and emphasis is placed upon quantity of flow. Therefore, it was considered acceptable that the model develop satisfactory hydrographs and water quality predictions for normal discharge conditions. The translation process used in the model fulfills this objective.

The model as designed omits both bank storage and explicitly defined overland flow. However, the mean daily discharge data obtained from the network of input gages reflect to an undefined degree of bank storage. Therefore, the use of observed or simulated discharges as model input inherently produces hydrographs which reflect some effects of this storage. Locally added groundwater and discharges from ungaged tributaries are introduced to the model by means of the constants QAA and QAB. It has been assumed that these inflows are constant along the length of the stream or river. They are introduced at the upstream limit of each reach when they occur and are translated with the main discharge. These over simplifications of the natural process have greatly reduced the complexity of the model. The resulting hydrographs and water quality predictions are considered to be good reproductions of the historical data and attest to the adequacy of the translation procedure.

It was further assumed that hydrographs and water quality predictions could be developed by dividing discharges and quality loads into parts, with each part being a function of the time of flow required for the discharge to leave the reach. This assumption has reduced the complexity of the model and has made possible a relatively simple program which closely simulates conditions as found in nature. Steady flow conditions have been assumed to exist prior to the first days input. Therefore, discharges and water quality predictions can be determined for those days which would otherwise be omitted when day one's time of flow exceeds one day. The discrepancy which is introduced is relatively small and decrease in magnitude as the input for each new day is introduced. The first six days of output should, therefore, be questionable and not used.

The modified translation procedure consists of a series of logical IF statements and their associated mathematical expressions for determining the discharge and load by days and reach. The process is dependent upon the calculated time of flows (TF) for each day's discharge (QRCH). Each time of flow is compared to preassigned numerical values representing specific ranges. The range is associated with specific internal translation routines which calculate the quantities of QOUT (I,ND) and COUT (I,ND). Where I is the reach identification number and ND is the day.

This modification was developed because the translation technique used in the earlier version of the model (1) was found to occassionally skip consecutive daily integers when introducing the discharge input to a reach. This took place because the program used the total elapsed time of flow from day one for developing the daily subscripts. Skipping occurred when the integer portion of the new elapsed time exceeded the time previously calculated by more than two days.

The net effect of this error was relatively small in terms of the numerical output of the program. However, the flaw in the mathematical logic of the model was considered to be serious enough to warrant revision of the translation procedure.

The new computer program is given in Appendix A. The terms used in the program are defined in Appendix B. In discussing the program emphasis will be placed on the actual translation process. The various READ and WRITE statements will, therefore, not be reviewed.

The translation begins at the extreme upstream reach in the river network and progresses downstream. The process uses the statement cards from DO 60 LK = 1,226 to 60 continue in the program.

```
DO 60 LK  =  1,226
I  =  227 - LK
IF  (SKIP(I).LE.0) GO TO 60
```

DO 60 LK = 1,226 is the first fortran statement of the translation routine. The dummy variable LK is used as a counter and is given numerical values from 1 to 226. I = 227 - LK utilizes LK to calculate values of the reach identification I. The logical IF statement compares the value of the SKIP vector for reach I with zero. If the reach exists the translation procedure is begun, if the reach does not exist the procedure is bypassed and a new value for I is established.

```
JR1  =  UR1 (I)
JR2  =  UR2 (I)
JG1  =  IG1 (I)
JG2  =  IG2 (I)
```

Existing reaches are associated with two upper reaches and two stream gages. The fixed vector deck contains the identification number for each reach and gage. These four statements retrieve from memory storage the reach and gage identification numbers assigned to the reach undergoing the analyses. If the subscript variable is equal to 1, the reach and gage are nonexisting and their related parameters are equal to zero. The four nonsubscripted parameters are used as subscripts when recalling the gage and QOUT values associated with the reach being analyzed.

```
   NT  =  1.0
   GO TO 51
52 ITME  =  ITME + 1
   IF(ITME.GT.ND) GO TO 55
   GO TO 50
51 ITME  =  NT
```

The first day for each set of reach calculations is assigned the value of NT. 51 ITME = NT truncates NT and assigns the integer 1 to ITME. It is this value which is subsequently used for subscripting the variables QOUT and COUT for day 1. Statement 52 ITME = ITME + 1 is used repeatedly to update the day after the translation process has been completed for the day in question. The logical IF following statement 52 is a safety check which stops the calculations when the routine surpasses the number of days assigned to the hydrographs being analyzed.

```
QADD  =  QAA(I)* (GAGE(JG1,ITME) + GAGE(JG2,ITME)) +
         QAB(I)
QRCH(ITME)  =  QADD + QOUT(JR1,ITME) + QOUT(JG2,ITME)
IF(QRCH(ITME).LT.1.0)QRCH(ITME)  =  1.0
```

The locally added discharge and the discharge in the reach are calculated for each existing reach. When end reach values are calculated, QADD is equal to the daily values of the input hydrograph and QRCH(ITME) is equal to QADD with no translation. The QADD and QRCH for reach 4 are determined in the same fashion, except that QRCH is determined from a mathematically derived hydrograph based upon discharges for the Wakarusa River at Lawrence, Kansas.

```
     IF(I.NE.NPT(NNN)) GO TO 600
     LNUMB  =  NUM(NNN)
     DO 608 K  =  1,LNUMB
     CADD  =  A(NNN,K)*QRCH(ITME)**B(NNN,K)
     IF(QCRIT(NNN).GT.QRCH(ITME)) GO TO 2001
 608 CONTINUE
```

The parameter NPT(NNN) represents end reach identification numbers. Numerical values for NPT(NNN) are assigned in the DATA statement in a descending order. The logical IF determines whether or not an end reach is being analyzed. If I equals NPT(NNN) the five following statements are used for calculating the inorganic load added to the river at the furthest upstream points within the model area. If I is not equal to NPT, a transfer is made to the internal reach routine.

LNUMB is the dummy variable which represents the number of end reach inorganic data cards assigned to the reach and stored in memory. CADD is a function of QRCH and is a hyperbolic relationship with parameters A and B obtained from preliminary noncomputer calculations. The IF statement compares the QCRIT value with the calculated value of QRCH(ITME). When QCRIT is greater than QRCH(ITME), the CADD value has already been calculated. When QCRIT is less than or equal to QRCH(ITME), CADD must be calculated. This particular DO loop is repeated LNUMB number of times or until QCRIT exceeds QRCH(ITME). The last calculated value of CADD represents the total tonnage of the inorganic species which is placed into the end reach. Previously calculated CADDs are not retained. However, the inputted values of QCRIT, A and B are retained in storage for future use.

```
  600   IF(QADD.GE.QADC(I)) GO TO 2000
        CADD  =  CAA(I)*(QADD**CAB(I))
        GO TO 2001
 2000   IF(QADD.GE.QADC2(I)) GO TO 2002
        CADD  =  CAC(I)*(QADD**CAD(I))
        GO TO 2001
 2002   CADD  =  CAE(I)*(QADD**CAF(I))
```

This group of fortran statements calculate the inorganic load which is added locally. When control has been transferred to the 600 statement a search is undertaken to determine which set of variables best describes the inorganic load for the existing QADD. A maximum of three flow ranges are possible. The value for CADD is calculated and the next statement is reached.

```
2001 CRCH(ITME)  =  CADD + COUT(JR1,ITME) + COUT(JR2,ITME)
```

The total inorganic load for the reach in question is composed of locally added loads and loads which are already in the reach. Statement 2001 sums daily the individual loads for the reach in question.

```
V  =  VA(I)*QRCH(ITME)**VB(I)
TF =  L(I)/(16.4*V)
```

Velocity and time of flows are calculated for each day's discharge by these equations. The constant 16.4 changes the velocity from feet/sec to miles/day, thereby establishing TF in days.

```
IF(TF.LT.1.0) GO TO 1000
IF(ITME.NE.1) GO TO 2
QOUT(I,1)  =  QRCH(1)
COUT(I,1)  =  CRCH(1)
```

This group of statements is representative of eight similar groups contained in the translation control section. The control section of the program is composed of the statement cards from IF(TF.LT.1.0) GO TO 1000 to IF(TF.GE.9.0) GO TO 1017, inclusive. Each group of statements has the distinct function of determining the subscript and translation routine which is applicable. Beginning with the

IF(TF.LT.1.0) GO TO 1000 statement, the program makes the initial comparison of the calculated time of flow with a predetermined limit. If TF is greater than 1.0 the next IF statement is utilized. This logical comparison is used to install values into the hydrograph and water quality arrays for day 1, thus utilizing the assumption that steady flow conditions exist prior to the start of the modeling period. When ITME equal 1, QOUT(I,1) and COUT(I,1) are equated to their respective reach values.

Having introduced values into QOUT(I,1) and COUT(I,1) the process then calls for statement number 2 to be utilized. This process is repeated until one time of flow comparison produces positive results. Control is then transferred to the subscript and translation section of the program. If, for instance, we assume that statement number 4 utilizes the time of flow comparison, the program then calls for a bypass of the remaining statements in the control section and a transfer to statement number 1005.

```
1005    ITME7 = ITME + 3
        IF(ITME1.GT.ND) GO TO 52
        QOUT(I,ITME7) = QOUT(I,ITME7) + QRCH(ITME)
        COUT(I,ITME7) = COUT(I,ITME7) + CRCH(ITME)
        GO TO 52
```

At this point in the translation analysis it becomes necessary to establish the subscript which represents the day when the inputted discharge and load leaves the reach.

Therefore, since it has been assumed that the time of flow is equal to 3.0 days, the exit day is simply 3.0 days following input. The IF(ITME7.GT.ND) GO TO 52 statement acts as a check within the model. Its function is to eliminate the possibility of generating discharges and loads beyond the desired hydrograph and qualigraph time base. In addition, it assures the user that the core storage allocated to the variables QOUT(I,ND) and COUT(I,ND) is not surpassed. The next two fortran statements calculate the discharge and load which leaves the reach during the day denoted by the subscript ITME7. The procedure calls for the computer to recall previously calculated values of QOUT(I,ITME7) and COUT(I,ITME7) which may have been generated by earlier inputs into the reach. The discharge and load which entered on ITME day now leave the reach in their entirety. The GO TO 52 statement causes a return to the beginning of the Transmac process where the next input day's subscript is established and the translation is repeated.

Variables having the form F__, where the blanks contain integers from 1 to 16, are time-dependent distribution factors. These variables are used repeatedly throughout the translation section of the model. Their only function is to divide the quantities of QRCH(ITME) and CRCH(ITME) into parts, thereby accounting for the time of flow.

The exact magnitude of the first F__ variable contained in each translation routine represents the time remaining in a day and establishes the percentage of discharge and load leaving the reach. The second F__ variable is numerically equal to the decimal fraction of the time of flow. It therefore, it the factor which establishes the quantity of QRCH(ITME) and CRCH(ITME) which is unaccounted for and which must be placed in the following day.

Following the calculations of the QOUT and COUT which result from the distribution of QRCH(ITME) and CRCH(ITME) control is once again transferred to statement 52. The daily subscript is then incremented by 1 and the process is repeated.

When the time of flow equals or exceeds nine days, the control section transfers to statement 1017. This statement calls for the print-out of a statement informing the user of the conditon and an immediate termination of the Transmac process takes place. The program then returns control to statement number 10 and new set of input discharge data is introduced for analysis.

The program can easily be expanded so that times of flow exceeding nine days can be analyzed. Additional control statements and their related subscripting and translation statements can be placed in the model at the users discretion. It is adviseable, however, to keep the number of these statements to a minimum so the computer space necessary for compilation of the model does not become excessive.

As was previously mentioned, when the number of days analyzed for reach I exceeds the number of days assigned to the hydrograph a transfer to statement 55 is accomplished. This particular statement determines whether the reach just analyzed is designated for a print-out of the results. If the reach is so designated, the calculated values of COUT are transformed into mg/l and are tabulated with their corresponding days and discharges. The program then returns to the beginning of the DO 60 LK - 1,226 loop and the next downstream reach is analyzed. This determination is made following the analysis of each reach.

The final termination of the program occurs when the number of days (ND) assigned to a hydrograph is less than or equal to zero. One blank card located immediately following the last input discharge data card equates ND to zero and, thereby results in termination of the analysis.

IV. Conservative Water Quality

The geology of the Lower Kansas River basin is sedimentary. The region can be divided into three general regions for purposes of water quality characterization.

Rocks of Cretaceous age predominate in the area west of the junction of the Solomon and Smoky Hill Rivers. A significant stratigraphic unit in this area is the Dakota Formation which contains zones of a highly saline nature. Drainage from the Dakota Formation is thought to supply most of the dissolved solids, particularly chloride, originating in the lower reaches of the Solomon, the Saline, and the Smoky Hill Rivers.

The surface geology between the junction of the Solomon and the Smoky Hill Rivers and the town of Wamego on the Kansas River consists primarily of rocks of Permian age. These include a series of shales, limestones and sandstones all of which contain relatively large amounts of gypsum. This region contributes significant amounts of calcium, sulfate, carbonate, and some chloride to the river system.

The surface geology east of Wamego consists primarily of rocks of Pennsylvanian age. In this region, there are fewer bed rock outcrops north of the Kansas River, because of the loess and till mantle left by Quaternary glaciation. Significant amounts of calcium and carbonate enter the river system in this region. Relatively little chloride originates in this area.

The data for all of the long term water quality stations in the model region were grouped according to the classifications listed above and analyzed for functional relationships between discharge and each of the individual dissolved ions. Regression analyses by the method of least squares were investigated for the following equations:

(1) $C = aQ^b$

(2) $C = 10^{(d + eQ)}$

(3) $C = f + gQ$

(4) $C = h + i(\log Q)$

(5) $C = j + k/Q$

(6) $C = l + mQ + nQ^2 + \text{---}pQ^5$

where C = concentration of the individual ion in milligrams per liter.

Q = discharge in cubic feet per second.

$a, b, \text{---}p$ = constants, coefficients, or exponents.

Equations one and two exhibited the highest correlations between stations within a single geologic grouping and between the individual dissolved ion concentrations at a single station. The equation selected and the regression constants are given in Table 2.

These equations were used as the basis for the development of chloride, sulfate, calcium and magnesium conservative add vectors for the Lower Kansas River Basin Model. These vectors were obtained by the correlation technique outlined in the earlier report (1). The discharge records

Table 2

Equations for Predicting the Concentration of Selected Naturally Occurring Conservative Pollutants as a Function of Discharge

Quality Station	Equation No.	Individual Ion	d	e	Correlation Coefficient
2	2	Cl	1.950	2.060×10^{-5}	-0.609
2	2	SO_4	2.028	1.908×10^{-5}	-0.610
2	2	Ca	1.905	7.416×10^{-6}	-0.413
2	2	Mg	1.231	1.270×10^{-5}	-0.457
5	2	Cl	2.013	2.500×10^{-5}	-0.739
5	2	SO_4	2.061	3.147×10^{-5}	-0.625
5	2	Ca	1.921	1.033×10^{-5}	-0.617
5	2	Mg	1.260	1.297×10^{-5}	-0.592
8	2	Cl	2.191	-5.625×10^{-5}	-0.779
8	2	SO_4	2.061	-2.989×10^{-5}	-0.580
8	2	Ca	1.942	-1.597×10^{-5}	-0.536
8	2	Mg	1.283	-2.264×10^{-5}	-0.513

Table 2 (Continued)

Quality Station	Equation No.	Individual Ion	d	e	Correlation Coefficient
9A	2	Cl	1.492	$-7.861\text{x}10^{-5}$	-0.874
9A	2	SO_4	1.711	$-3.490\text{x}10^{-5}$	-0.439
9A	2	Ca	1.805	$-2.178\text{x}10^{-5}$	-0.402
9A	2	Mg	1.169	$-3.772\text{x}10^{-5}$	-0.519
9B	2	Cl	1.271	$-2.152\text{x}10^{-5}$	-0.482
9B	2	SO_4	1.607	$-0.922\text{x}10^{-5}$	-0.208
9B	2	Ca	1.748	$-1.210\text{x}10^{-5}$	-0.383
9B	2	Mg	1.086	$-1.063\text{x}10^{-5}$	-0.249
11	2	Cl	1.686	$-1.823\text{x}10^{-4}$	-0.604
11	2	SO_4	1.947	$-1.240\text{x}10^{-4}$	-0.669
11	2	Ca	1.893	$-7.684\text{x}10^{-5}$	-0.510
11	2	Mg	1.222	$-7.651\text{x}10^{-5}$	-0.444
13	2	Cl	2.600	$-1.473\text{x}10^{-4}$	-0.773
13	2	SO_4	2.360	$-8.046\text{x}10^{-5}$	-0.621

Note: 9A - Big Blue River before construction of Tuttle Creek Reservoir
9B - Big Blue River after construction of Tuttle Creek Reservoir

Table 2 (Continued)

Quality Station	Equation No.	Individual Ion	d	e	Correlation Coefficient
13	2	Ca	2.064	-5.370×10^{-5}	-0.542
13	2	Mg	1.408	-6.548×10^{-5}	-0.514
16	2	Cl	2.170	-2.586×10^{-4}	-0.734
16	2	SO_4	2.223	-2.329×10^{-4}	-0.640
16	2	Ca	1.981	-6.954×10^{-5}	-0.485
16	2	Mg	1.289	-1.449×10^{-4}	-0.673
19	2	Cl	2.544	2.678×10^{-4}	-0.745
19	2	SO_4	2.377	1.840×10^{-4}	-0.686
19	2	Ca	2.048	7.008×10^{-5}	-0.582
19	2	Mg	1.405	1.514×10^{-4}	-0.685
24	2	Cl	2.025	1.084×10^{-4}	-0.833
24	2	SO_4	2.356	2.203×10^{-4}	-0.888
24	2	Ca	2.098	8.689×10^{-5}	-0.557
24	2	Mg	1.334	1.270×10^{-4}	-0.771

Table 2 (Continued)

Quality Station	Equation No.	Individual Ion	a	b	Correlation Coefficient
27	1	Cl	75.86	-0.3327	-0.859
27	1	SO_4	153.1	-0.2238	-0.740
27	1	Ca	109.9	-0.0653	-0.363
27	1	Mg	37.07	-0.1550	-0.546
22	1	Cl	386.4	-0.1454	-0.436
22	1	SO_4	226.5	-0.1037	-0.444
22	1	Ca	125.6	-0.0572	-0.391
22	1	Mg	30.97	-0.1326	-0.514
23	1	Cl	5,675.0	-0.6924	-0.953
23	1	SO_4	1,854.0	-0.4470	-0.876
23	1	Ca	286.4	-0.1795	-0.816
23	1	Mg	171.4	-0.3953	-0.930

used in developing and verifying the vectors are given in Table 3. In each case the vectors were developed using one set of four discharge records and then tested on another set of four.

The sets of chloride, sulfate, calcium and magnesium conservative add vectors developed for use in the Lower Kansas River Model are tabulated in Appendices C through F. These appendices also contain the conservative load vectors used to provide input to the model at the six future reservoir sites.

The input at Beloit, Kansas is presently defined by exponential equations. These data represent historical conditions prior to the closure of Glen Elder Dam. Russell, Kansas is located in Cretaceous rock. The historical data represents water quality conditions prior to the closure of Wilson Dam which is located in close proximity to the Russell station. Hyperbolic equations adequately represent the water quality measurements obtained for this station. The data for Langley, Kansas represents the water quality which can be expected from reservoirs. The regression analysis for this station resulted in essentially a constant ion concentration over the complete range of discharges when plotted on log-log paper. This can be attributed the homogenization of reservoir waters discussed later in this report. A hyperbolic equation with a small negative slope was used.

Table 3

Discharge Records Used in Developing and Verifying the Conservative Add Vectors used in the Lower Kansas River Basin Model.

February 15, 1961 - March 22, 1961
March 23, 1961 - April 27, 1961
August 26, 1961 - September 30, 1961
March 1, 1962 - April 5, 1962
November 1, 1962 - December 6, 1962
June 19, 1963 - July 24, 1963
June 1, 1964 - July 6, 1964
July 20, 1965 - August 24, 1965

Water quality data for Milford and Manhattan, Kansas, represent conditions prior to dam closure. This data is best described by the exponential equation as are other stations in the Permian region. The data at Valley Falls, Kansas, is described by a hyperbolic equation. This data is also for conditions prior to closure of Perry Dam.

The results which can be expected from these vectors are given in Figure 3 through Figure 26. The observed data points given in these Figures are grab sample values obtained from the appropriate Water Supply Papers of the U. S. Geological Survey.

The predicted concentration values were found to be identical in areas of flow duplications in the discharge records used in developing and in verifying the conservative add vectors. The predicted concentrations for all eight discharge records were therefore, plotted in Figure 3 to illustrate the results obtained over a wider range of discharge.

As mentioned in the previous report (1), the correlation technique for obtaining and adjusting the conservative add vectors is extremely time-consuming. Considerable effort has been devoted toward the development of a computer program for alleviating this difficulty. These efforts have not been successful up to the present time.

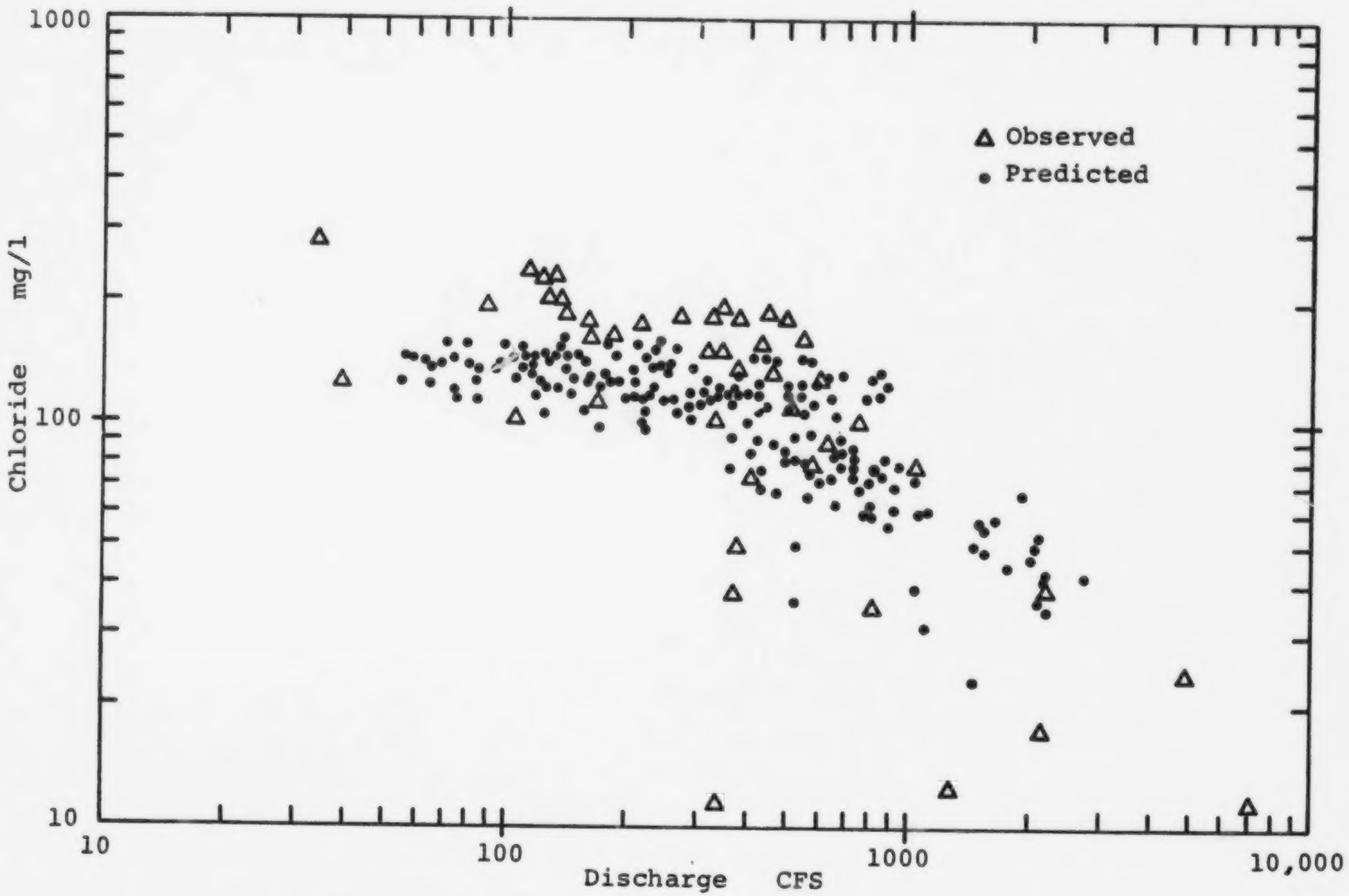


Figure 3 Observed and Predicted Chloride Concentration as a Function of Discharge
Quality Station No 16 - Solomon River at Niles

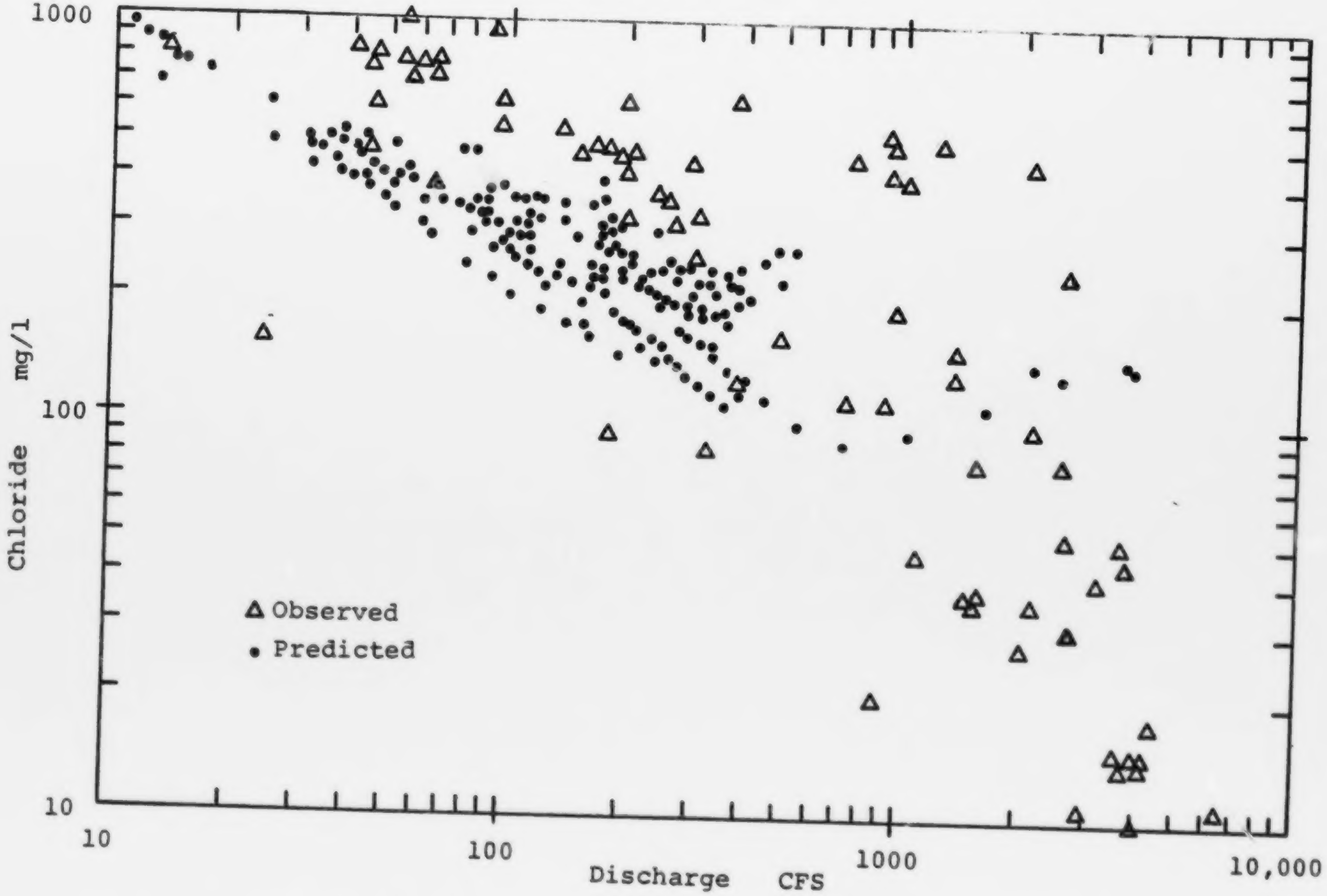


Figure 4 Observed and Predicted Chloride Concentration as a Function of Discharge
Quality Station No 19 - Saline River at Tescott

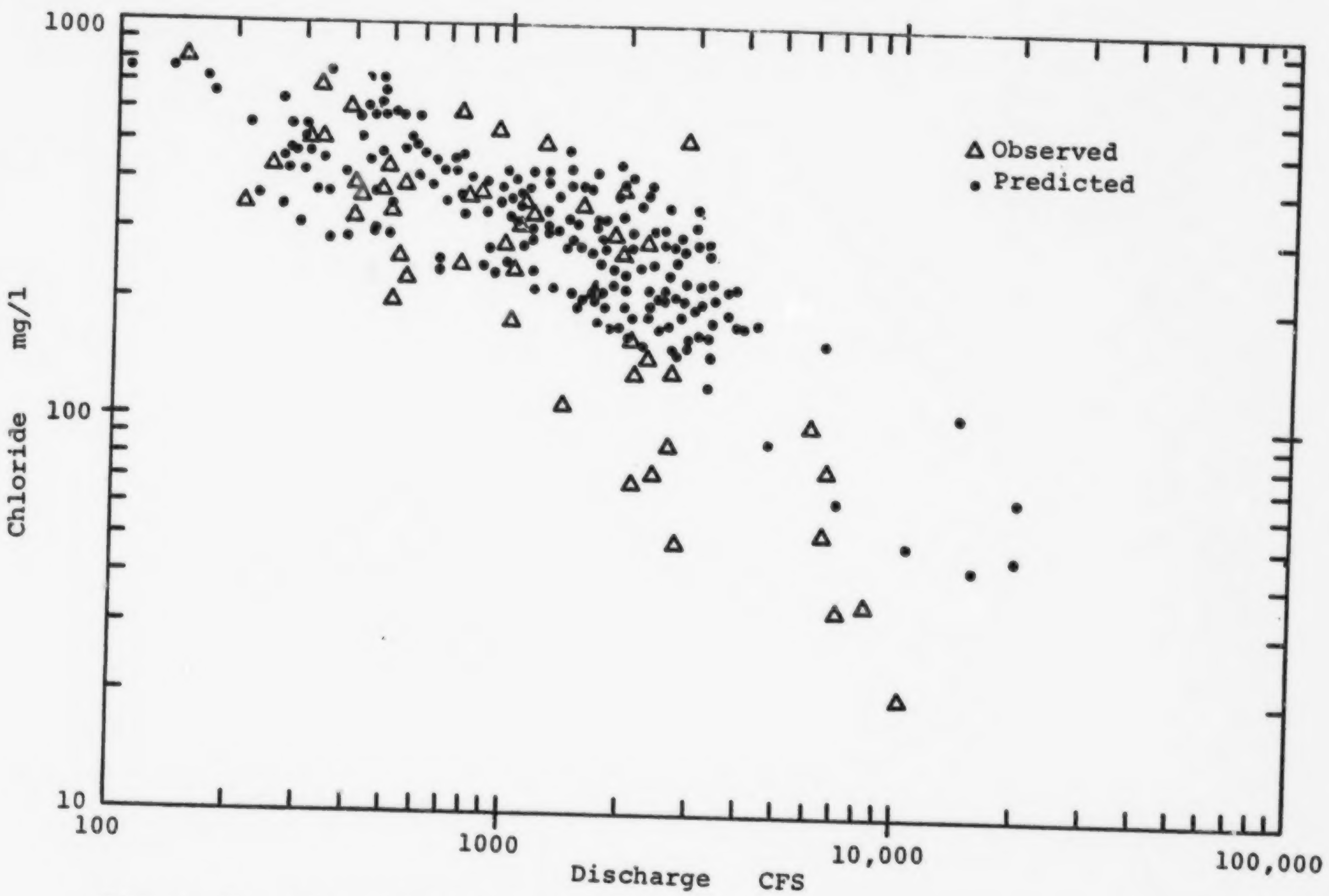


Figure 5 Observed and Predicted Chloride Concentration as a Function of Discharge
Quality Station No 13 - Smoky Hill River at Enterprise

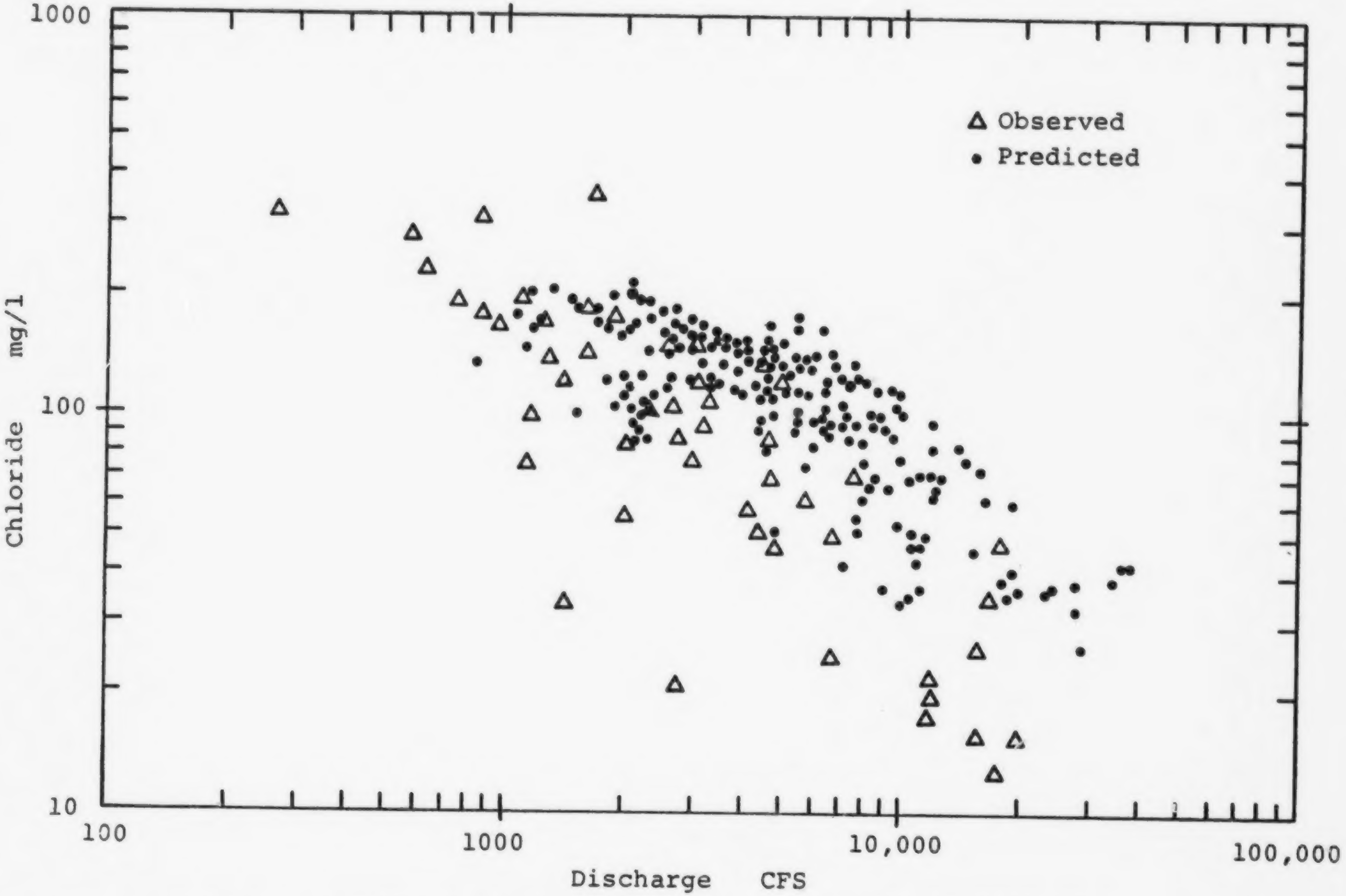


Figure 6 Observed and Predicted Chloride Concentration as a Function of Discharge
Quality Station No 8 - Kansas River at Wamego

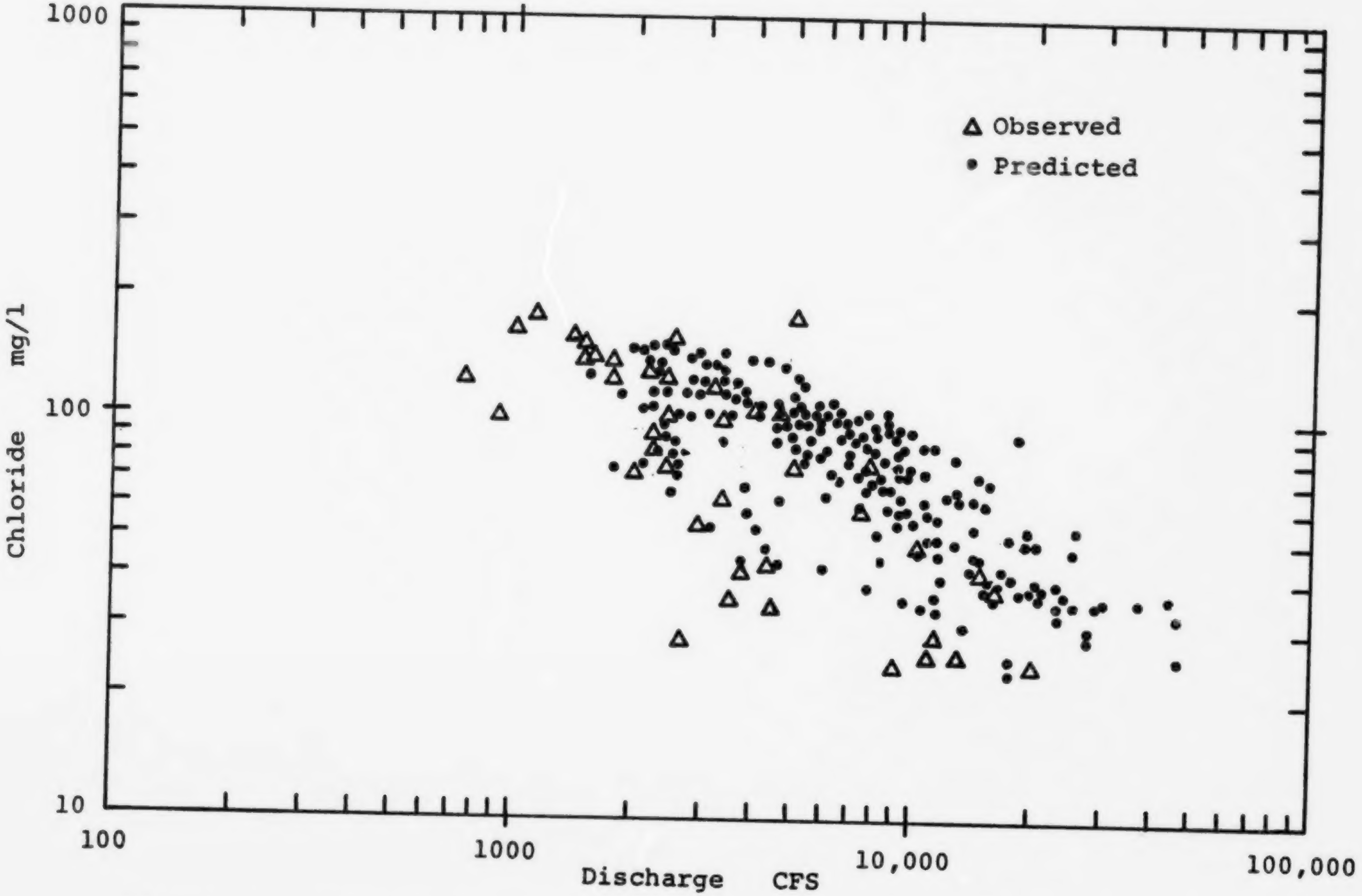


Figure 7 Observed and Predicted Chloride Concentration as a Function of Discharge
Quality Station No 5 - Kansas River at Lecompton

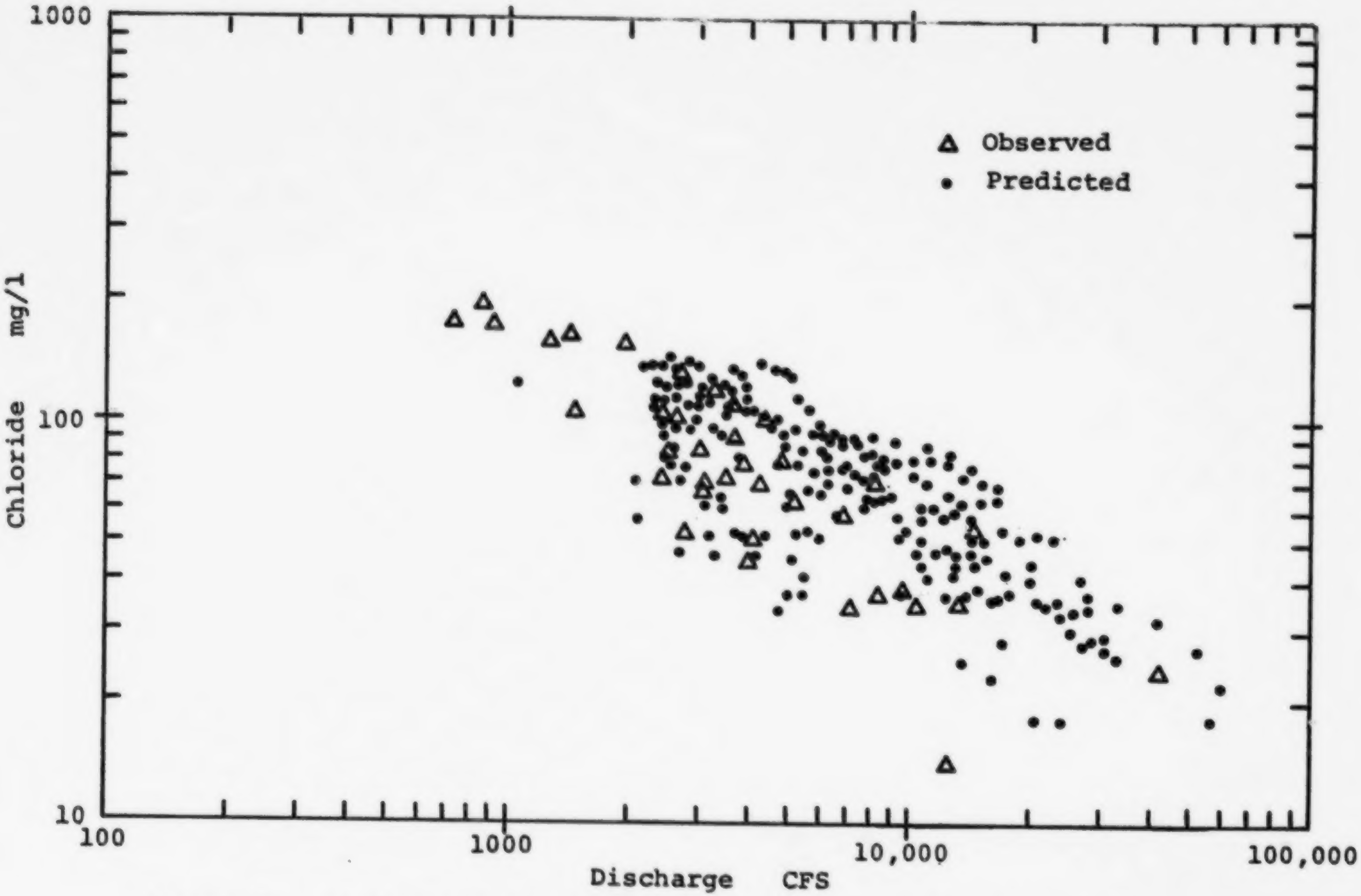


Figure 8 Observed and Predicted Chloride Concentration as a Function of Discharge
Quality Station No 2 - Kansas River at Bonner Springs

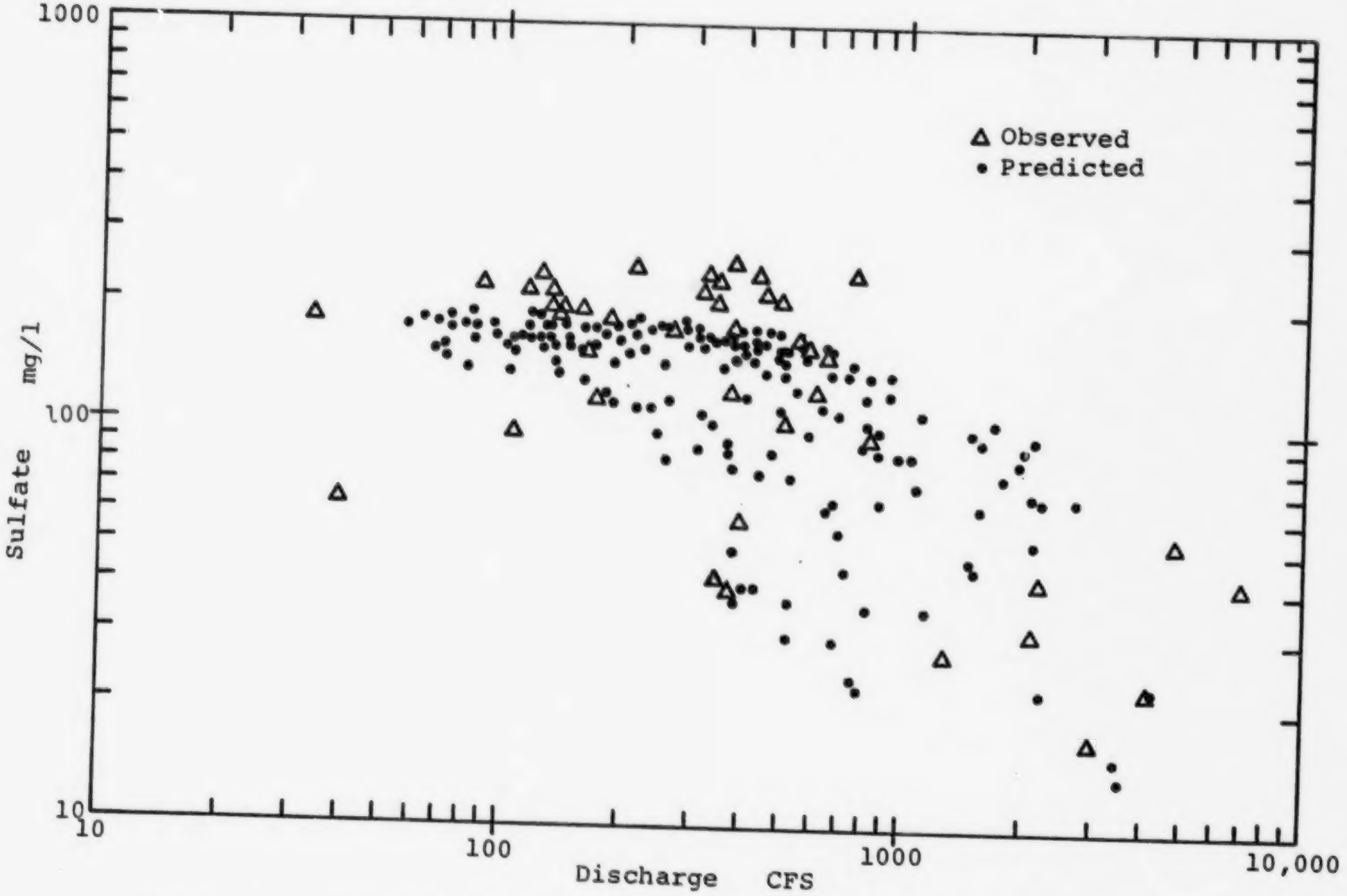


Figure 9 Observed and Predicted Sulfate Concentration as a Function of Discharge
Quality Station No 16 - Solomon River at Niles

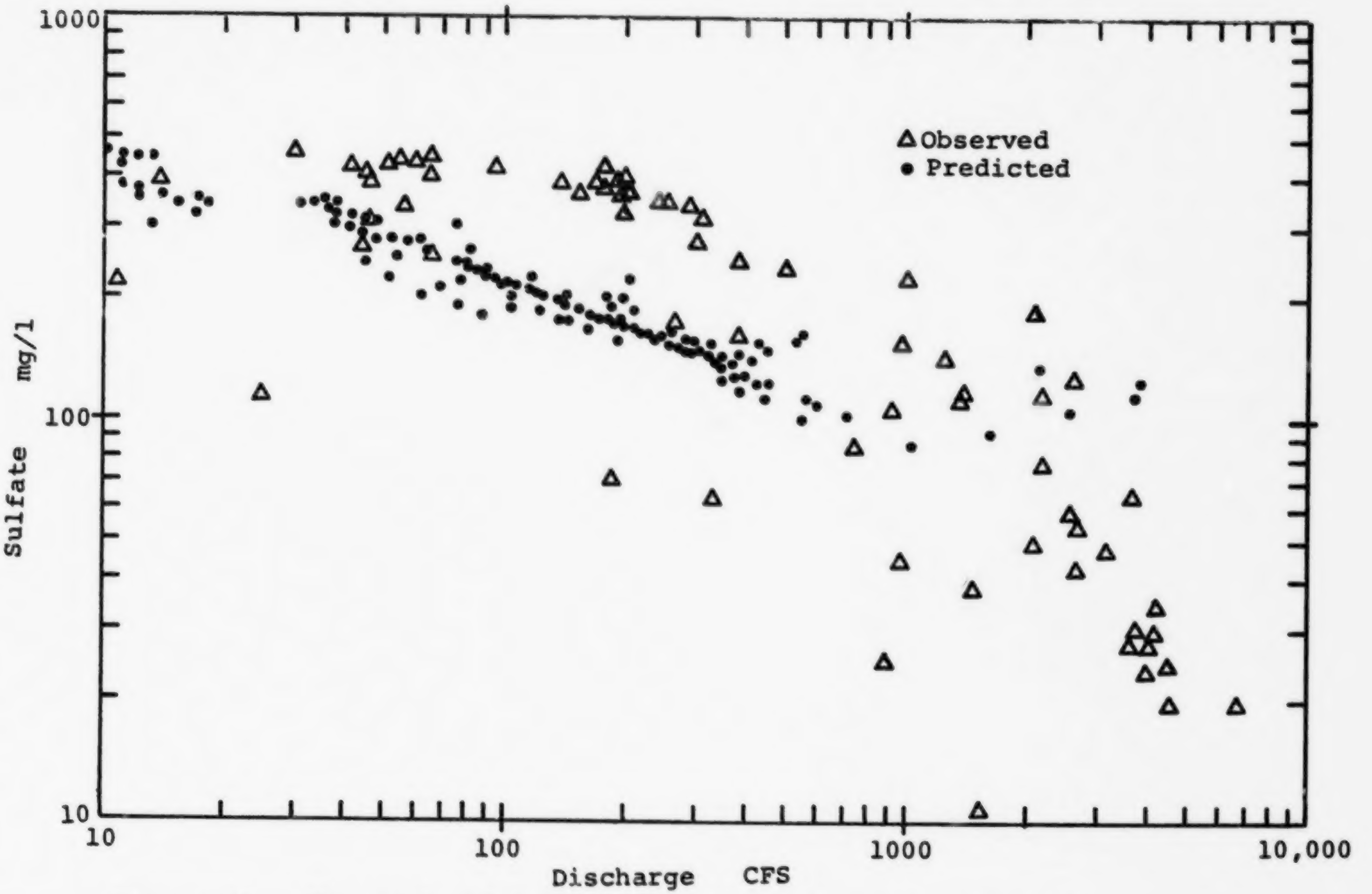


Figure 10 Observed and Predicted Sulfate Concentration as a Function of Discharge
Quality Station No 19 - Saline River at Tescott

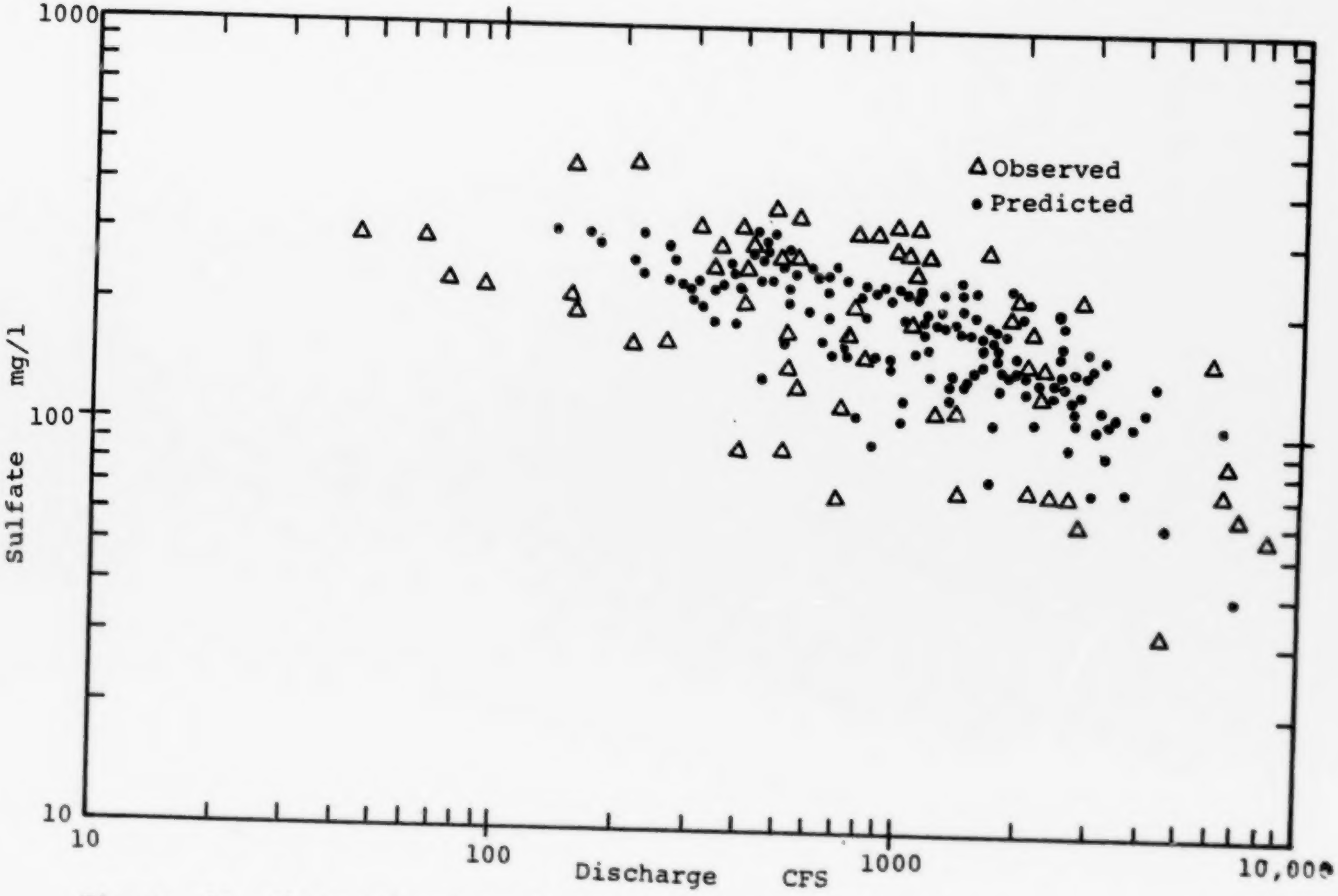


Figure 11 Observed and Predicted Sulfate Concentration as a Function of Discharge
Quality Station No 13 - Smoky Hill River at Enterprise

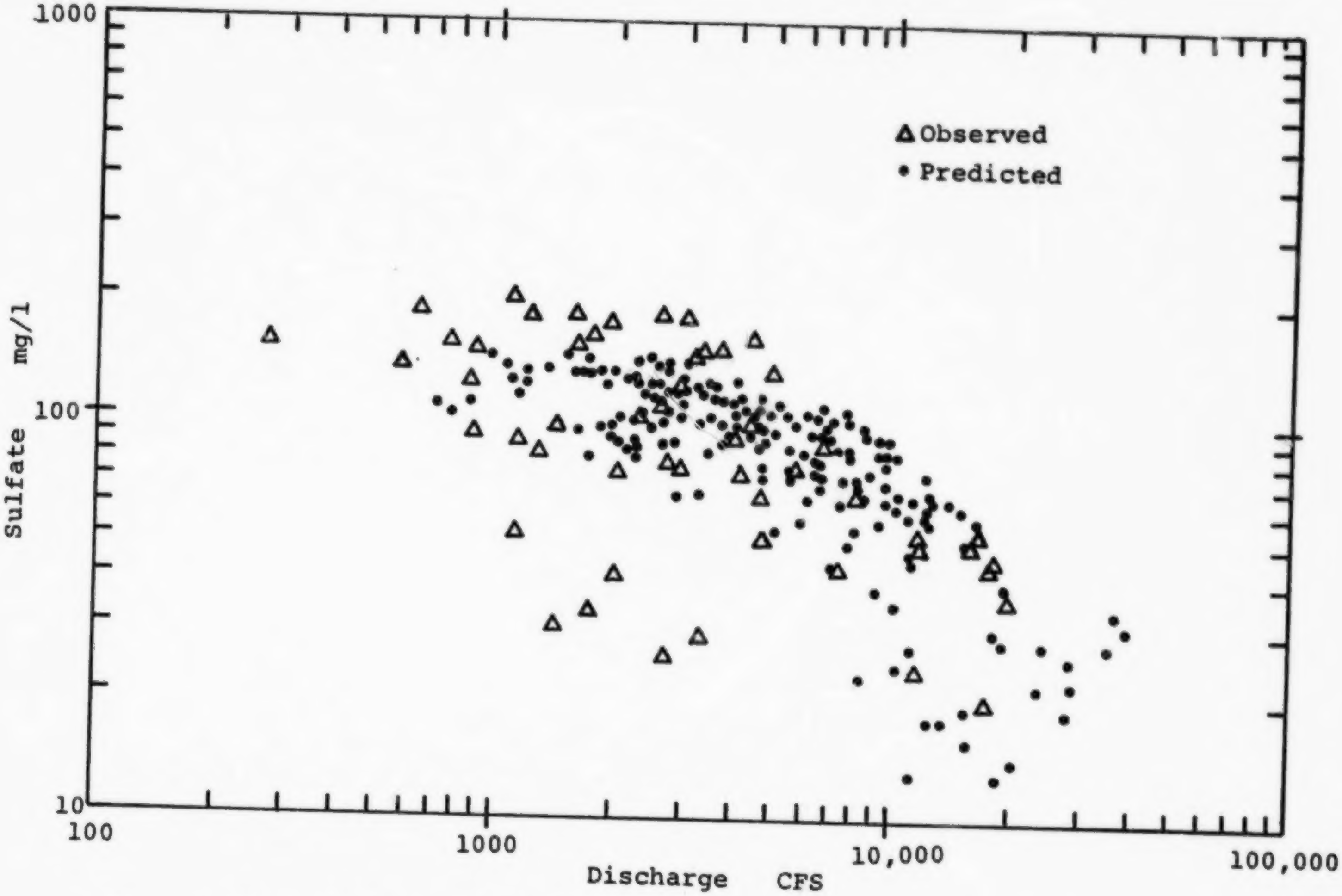


Figure 12 Observed and Predicted Sulfate Concentration as a Function of Discharge
Quality Station No 8 - Kansas River at Wamego

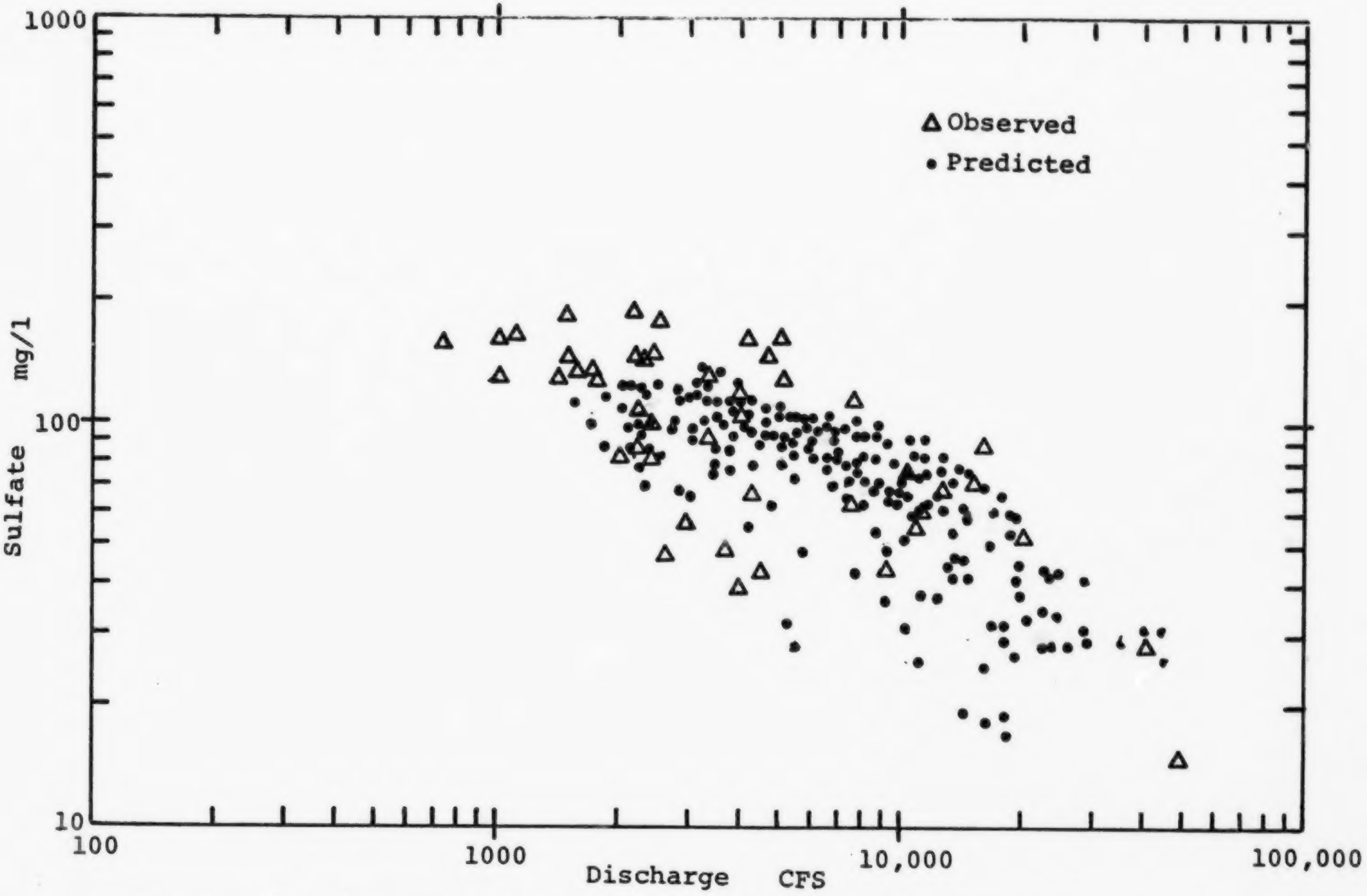


Figure 13 Observed and Predicted Sulfate Concentration as a Function of Discharge
Quality Station No 5 - Kansas River at Lecompton

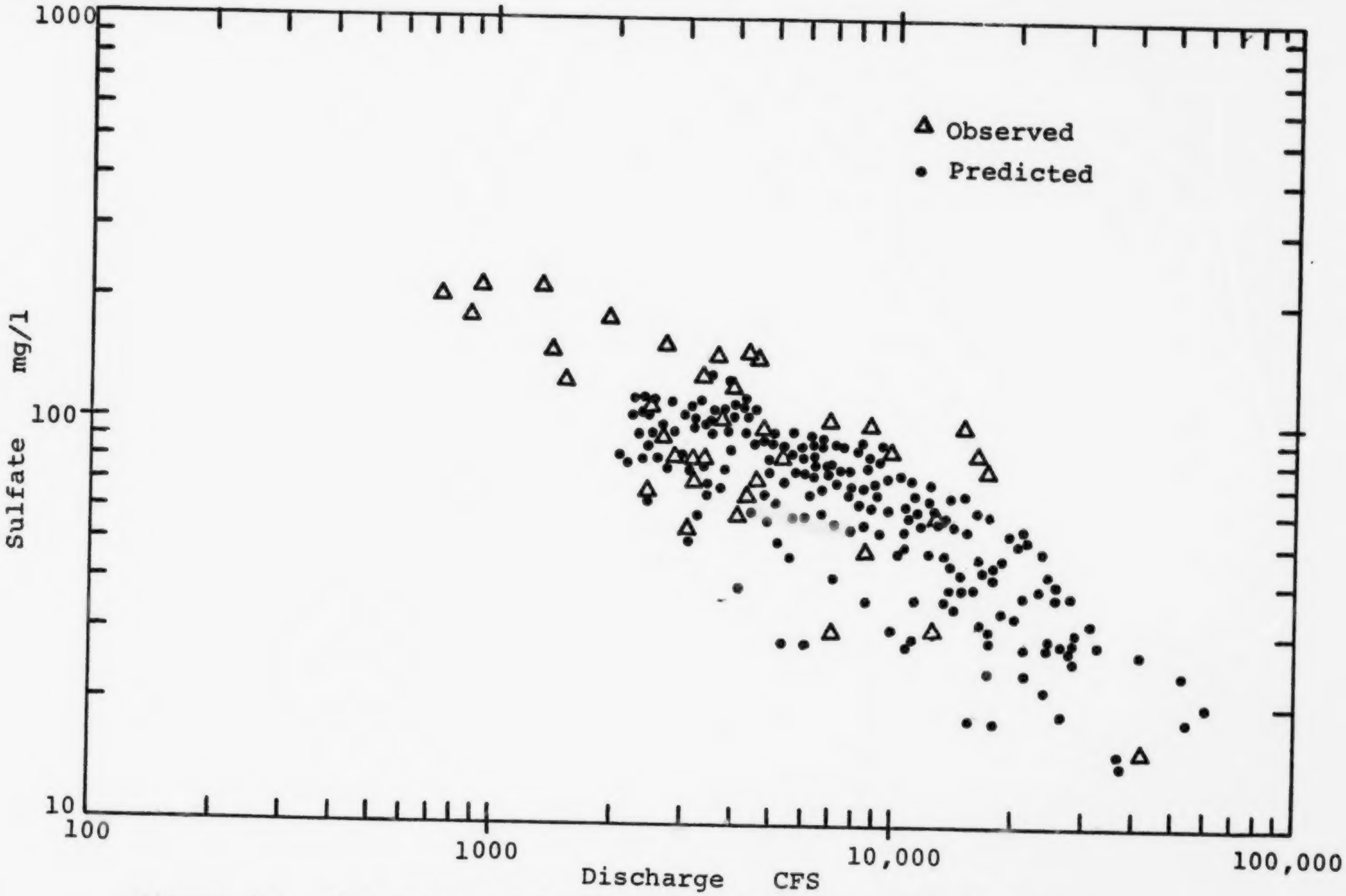


Figure 14 Observed and Predicted Sulfate Concentration as a Function of Discharge
Quality Station No 2 - Kansas River at Bonner Springs

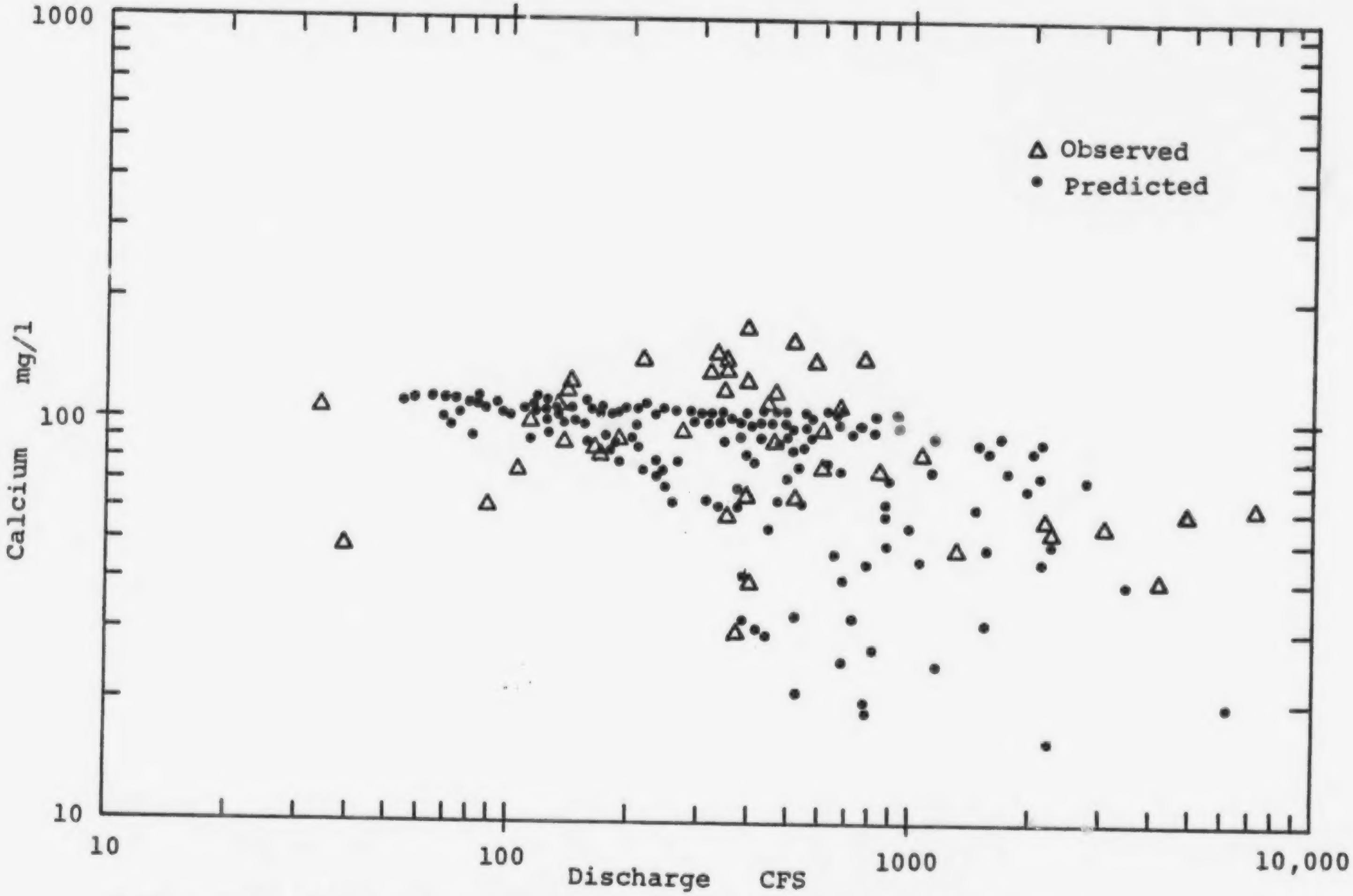


Figure 15 Observed and Predicted Calcium Concentration as a Function of Discharge
Quality Station No 16 - Solomon River at Niles

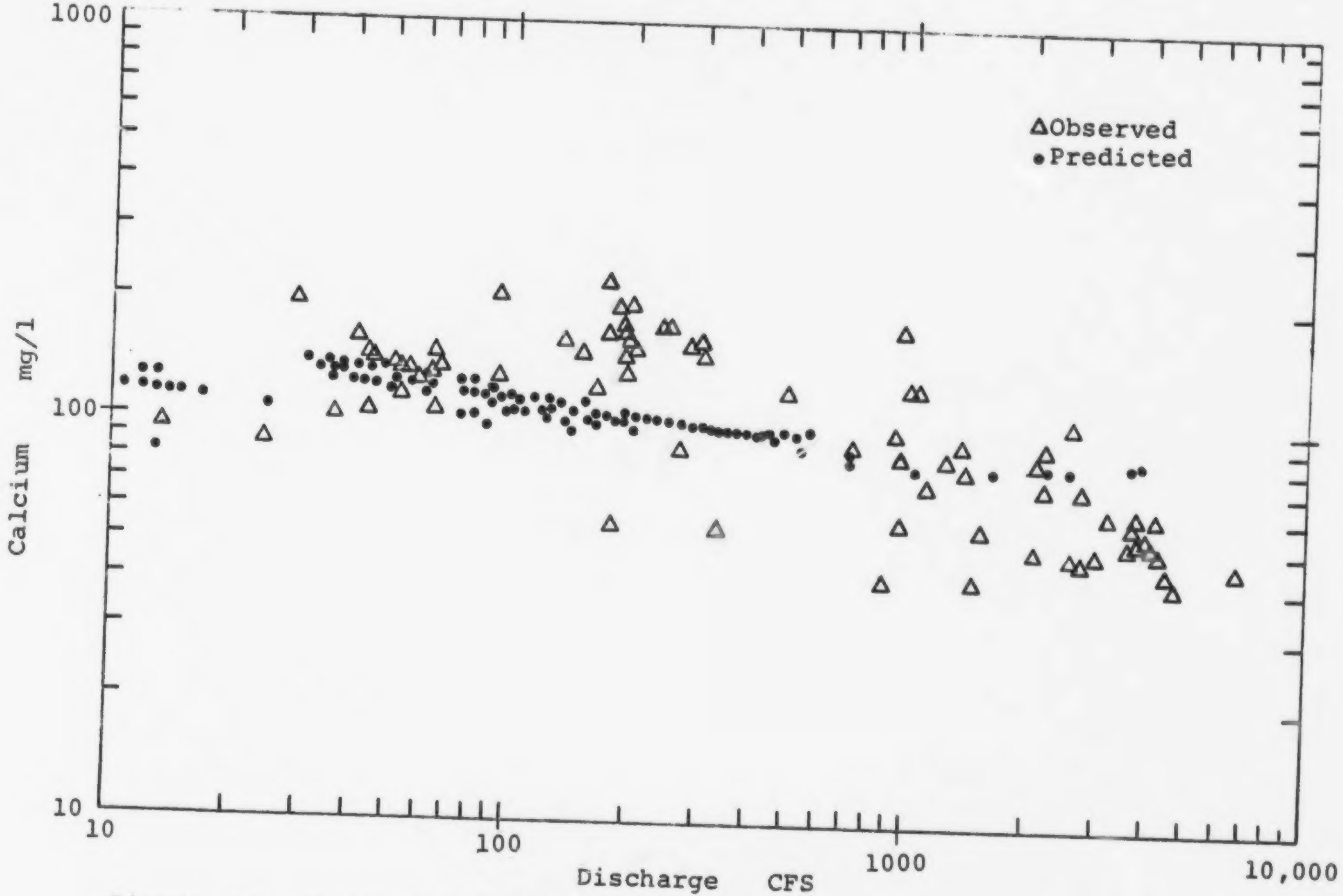


Figure 16 Observed and Predicted Calcium Concentration as a Function of Discharge
Quality Station No 19 - Saline River at Tescott

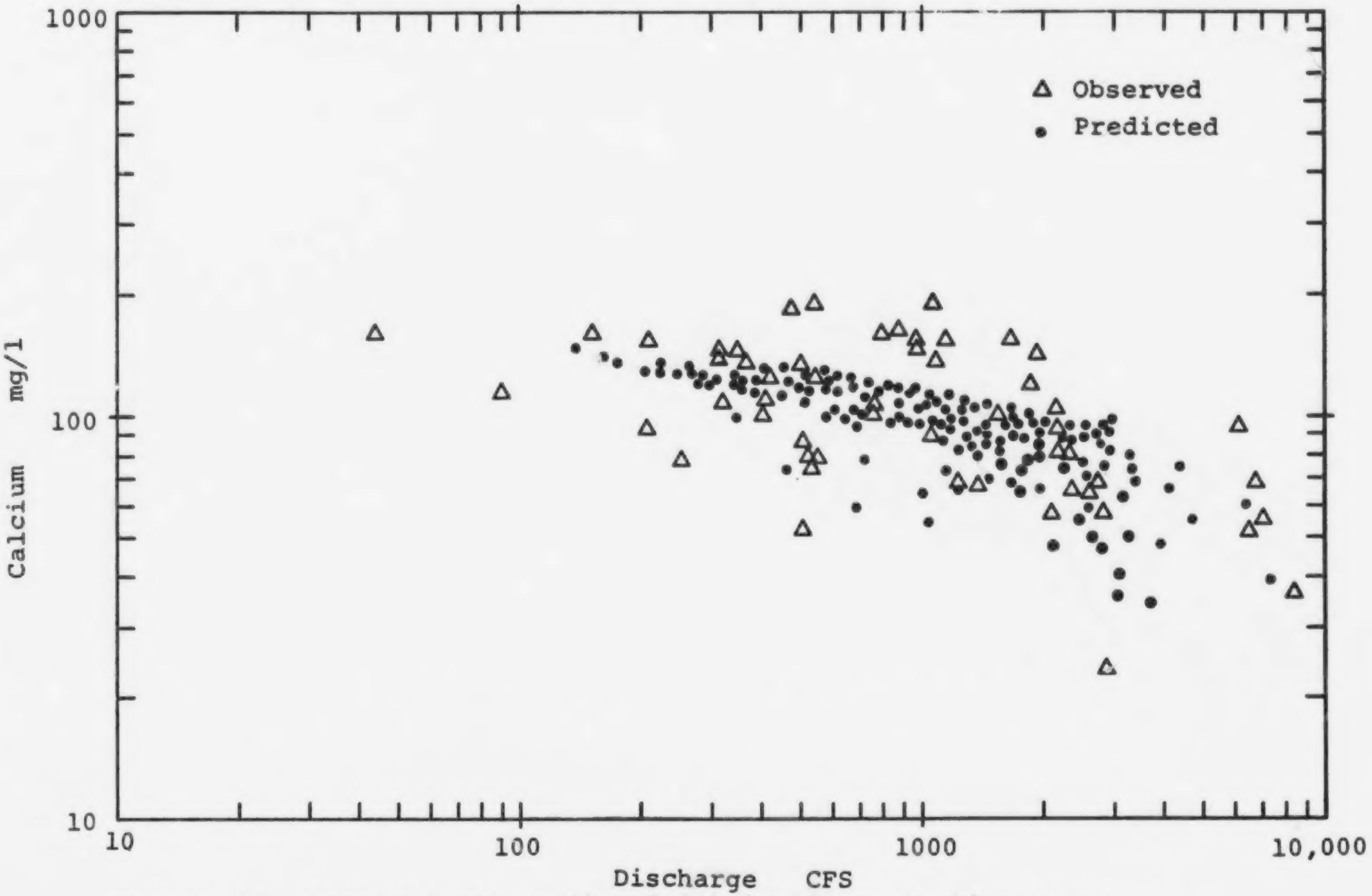


Figure 17 Observed and Predicted Calcium Concentration as a Function of Discharge
Quality Station No 13 - Smoky Hill River at Enterprise

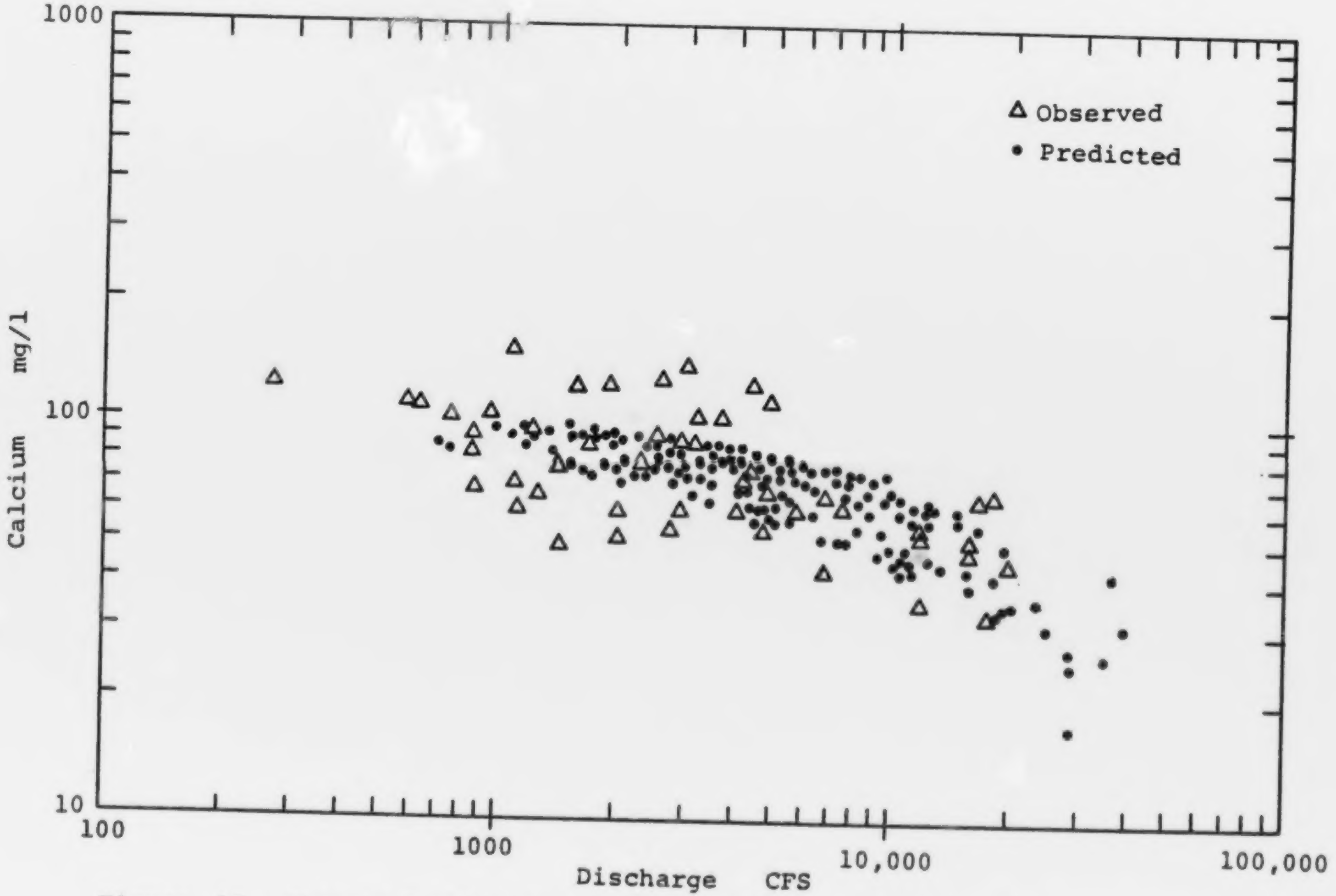


Figure 18 Observed and Predicted Calcium Concentration as a Function of Discharge
Quality Station No 8 - Kansas River at Wamego

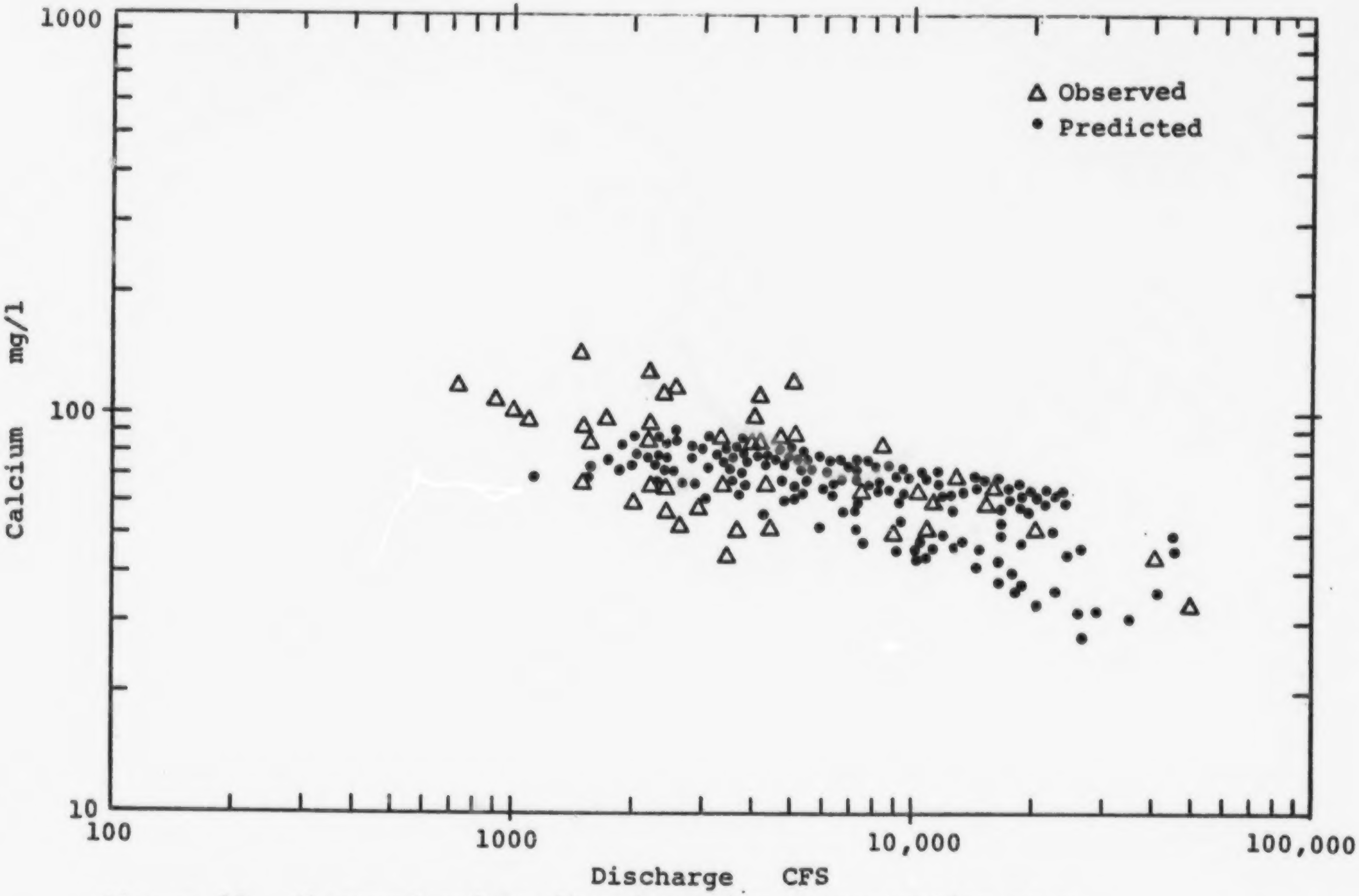


Figure 19 Observed and Predicted Calcium Concentration as a Function of Discharge
Quality Station No 5 - Kansas River at Lecompton

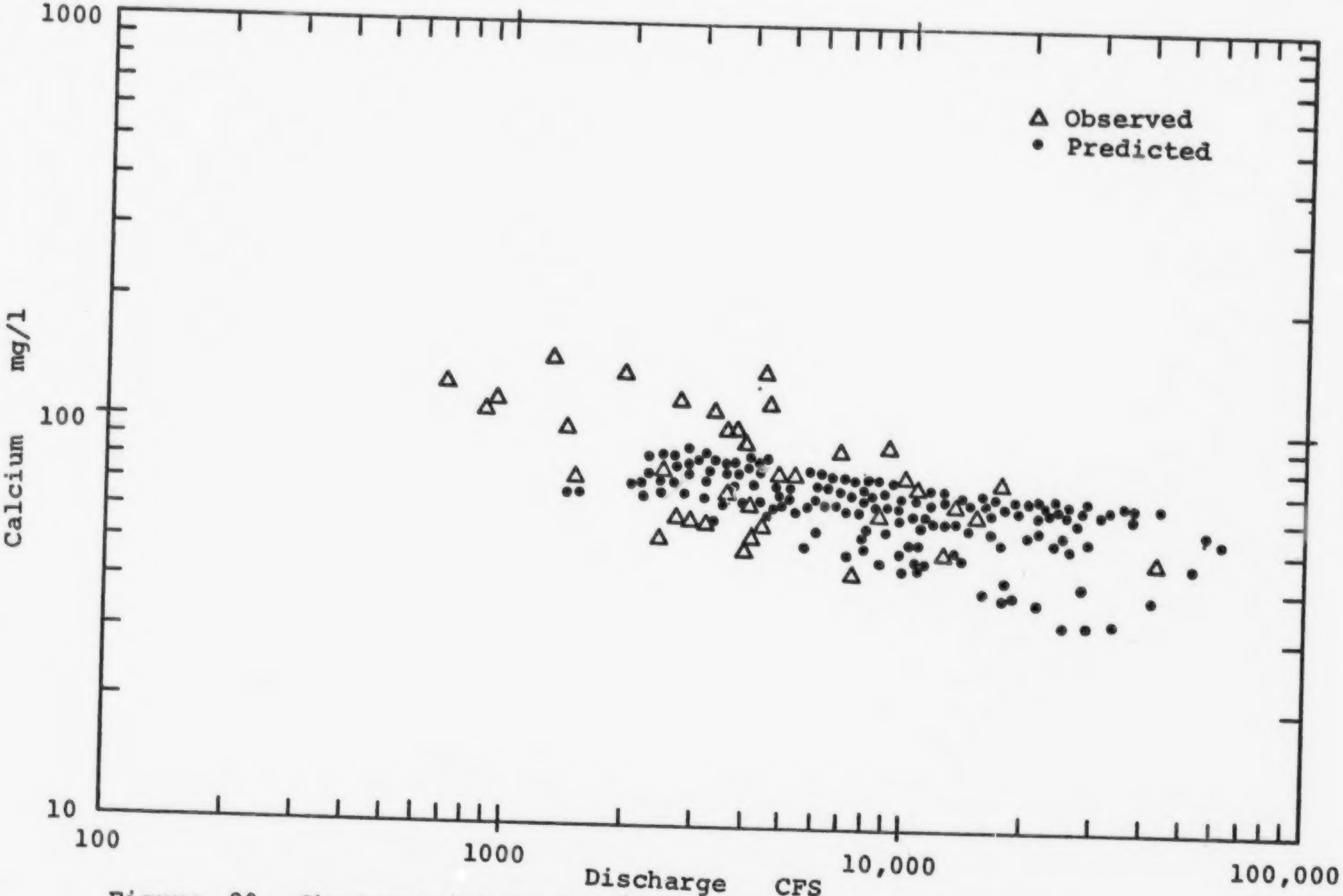


Figure 20 Observed and Predicted Calcium Concentration as a Function of Discharge
Quality Station No 2 - Kansas River at Bonner Springs

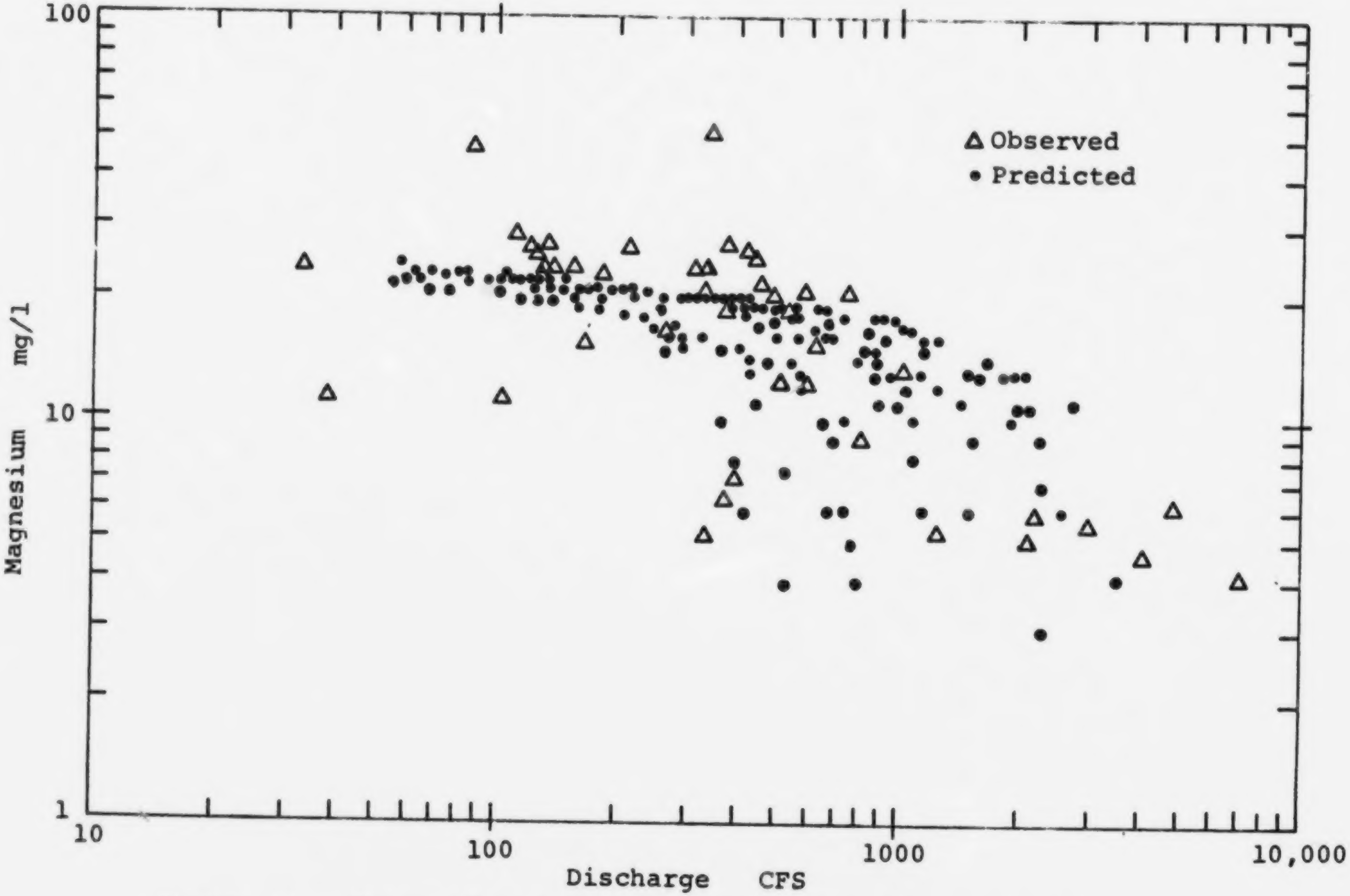


Figure 21 Observed and Predicted Magnesium Concentration as a Function of Discharge
Quality Station No 16 - Solomon River at Niles

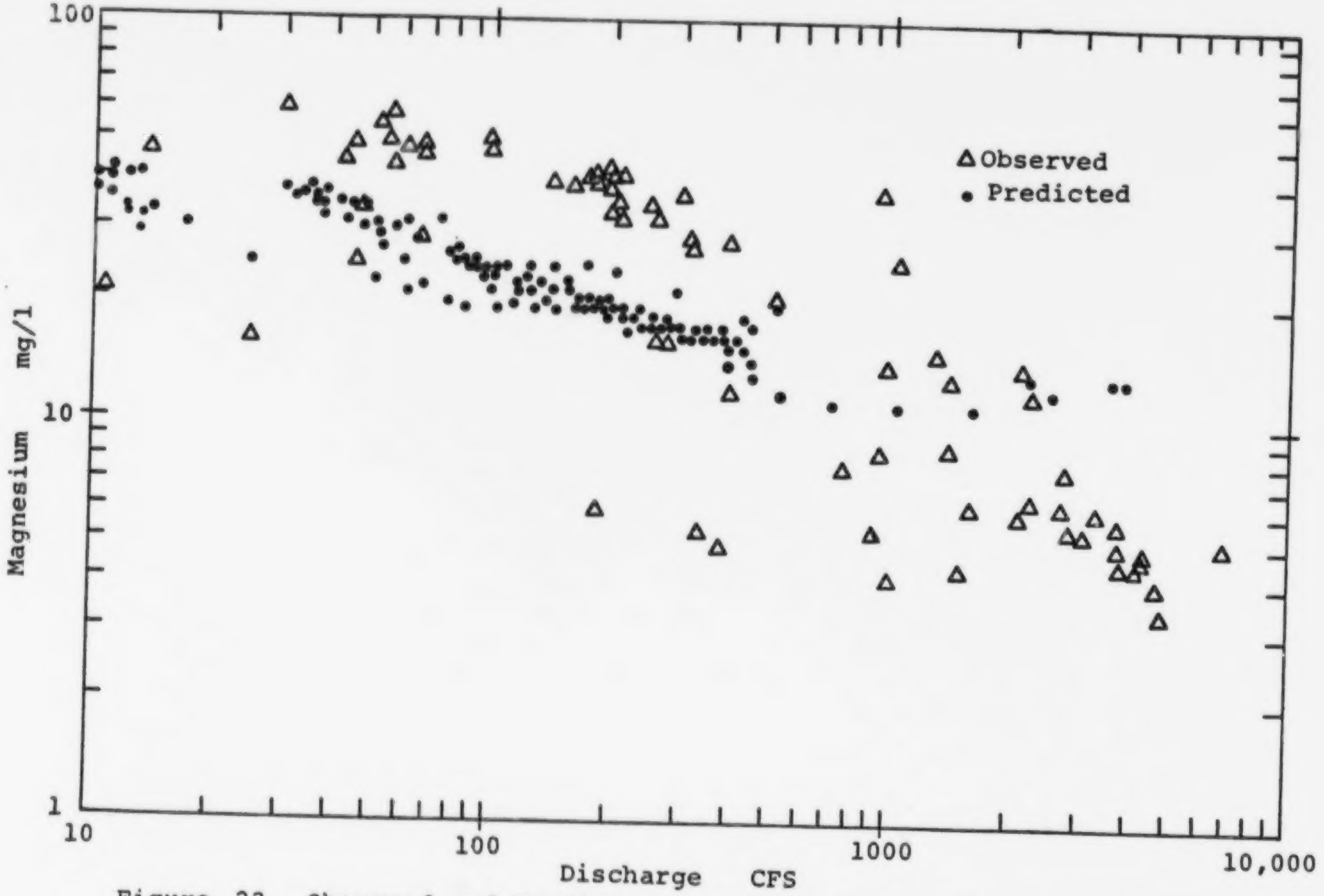


Figure 22 Observed and Predicted Magnesium Concentration as a Function of Discharge
Quality Station 19 - Saline River at Tescott

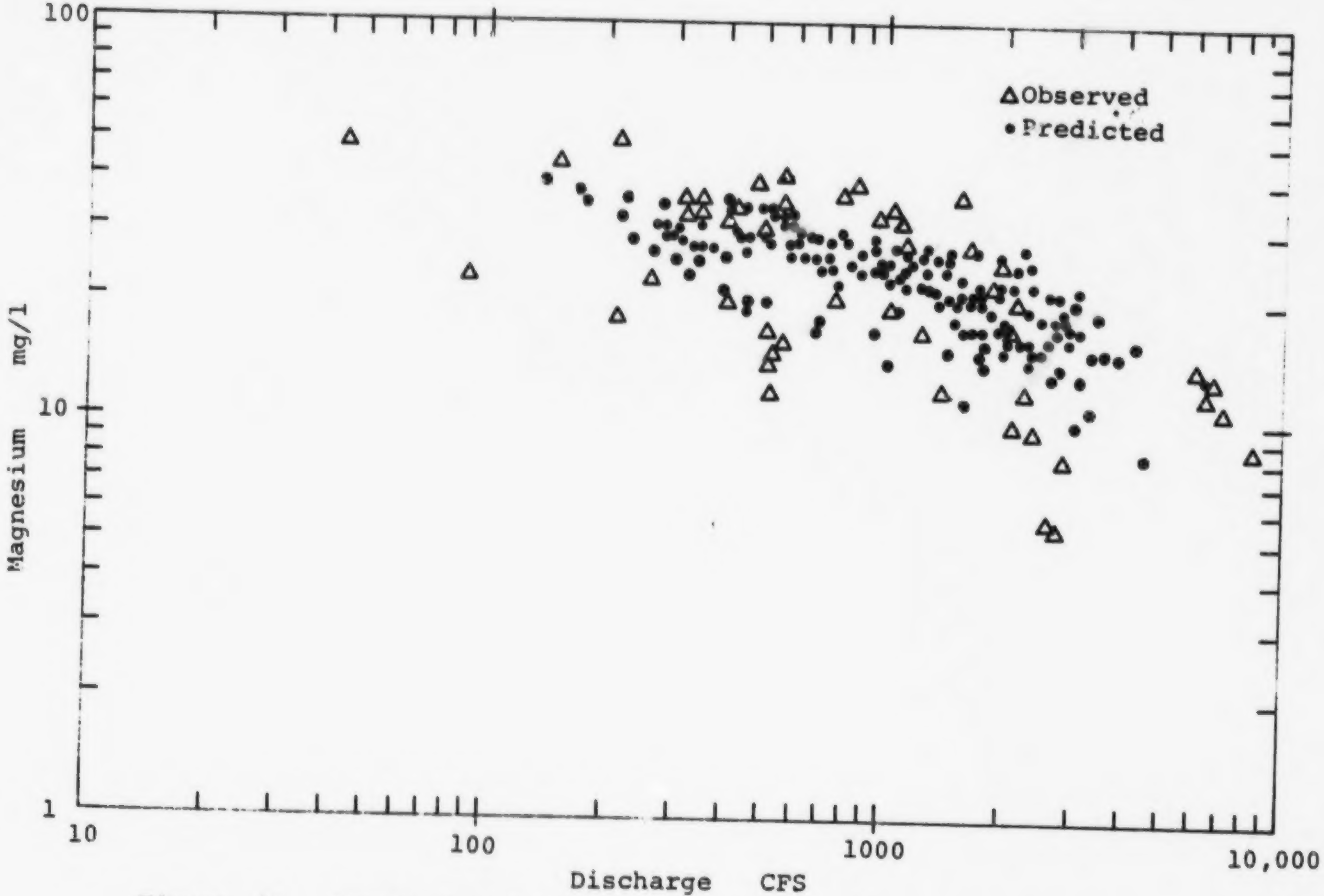


Figure 23 Observed and Predicted Magnesium Concentration as a Function of Discharge
Quality Station No 13 - Smoky Hill River at Enterprise

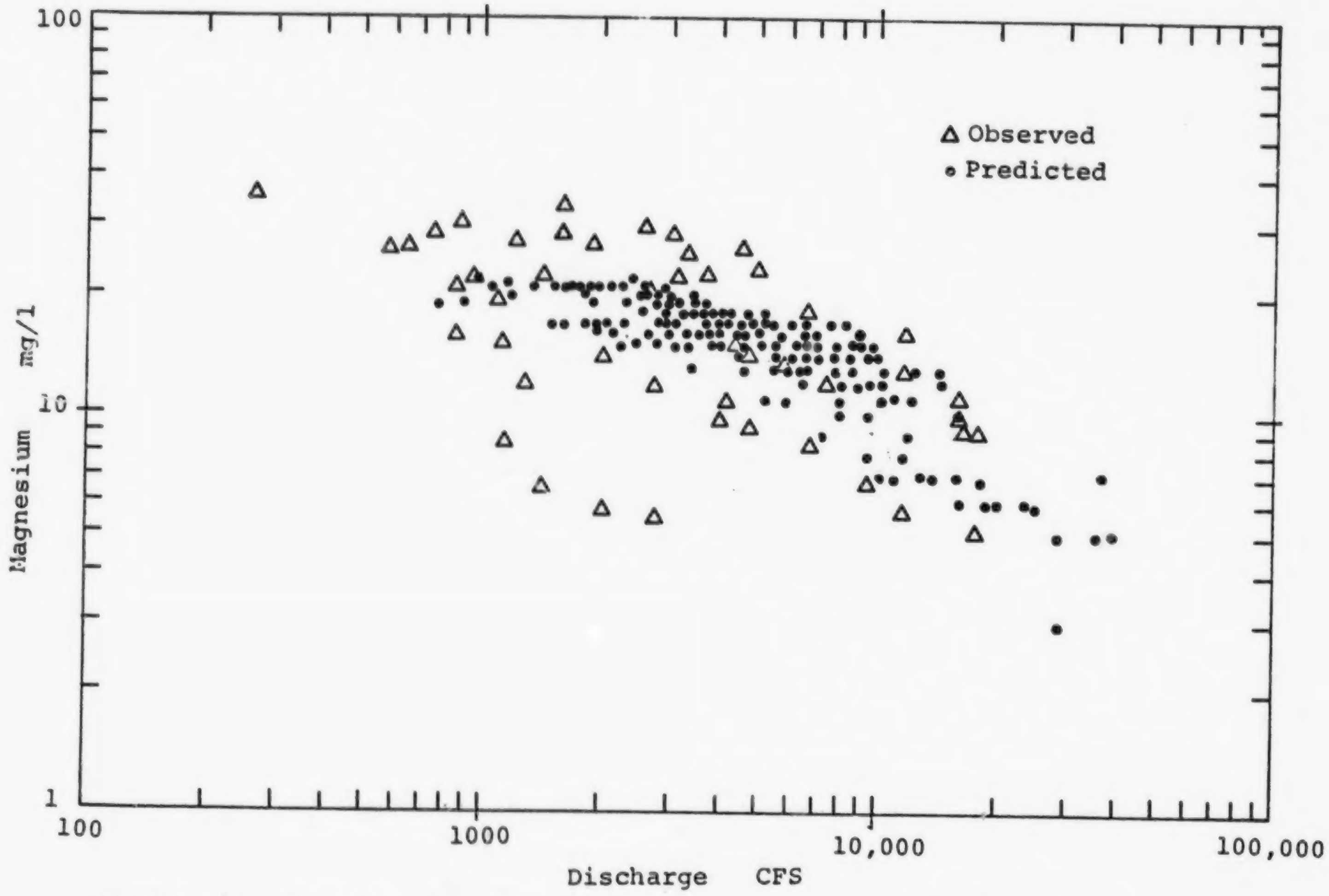


Figure 24 Observed and Predicted Magnesium Concentration as a Function of Discharge
Quality Station No 8 - Kansas River at Wamego

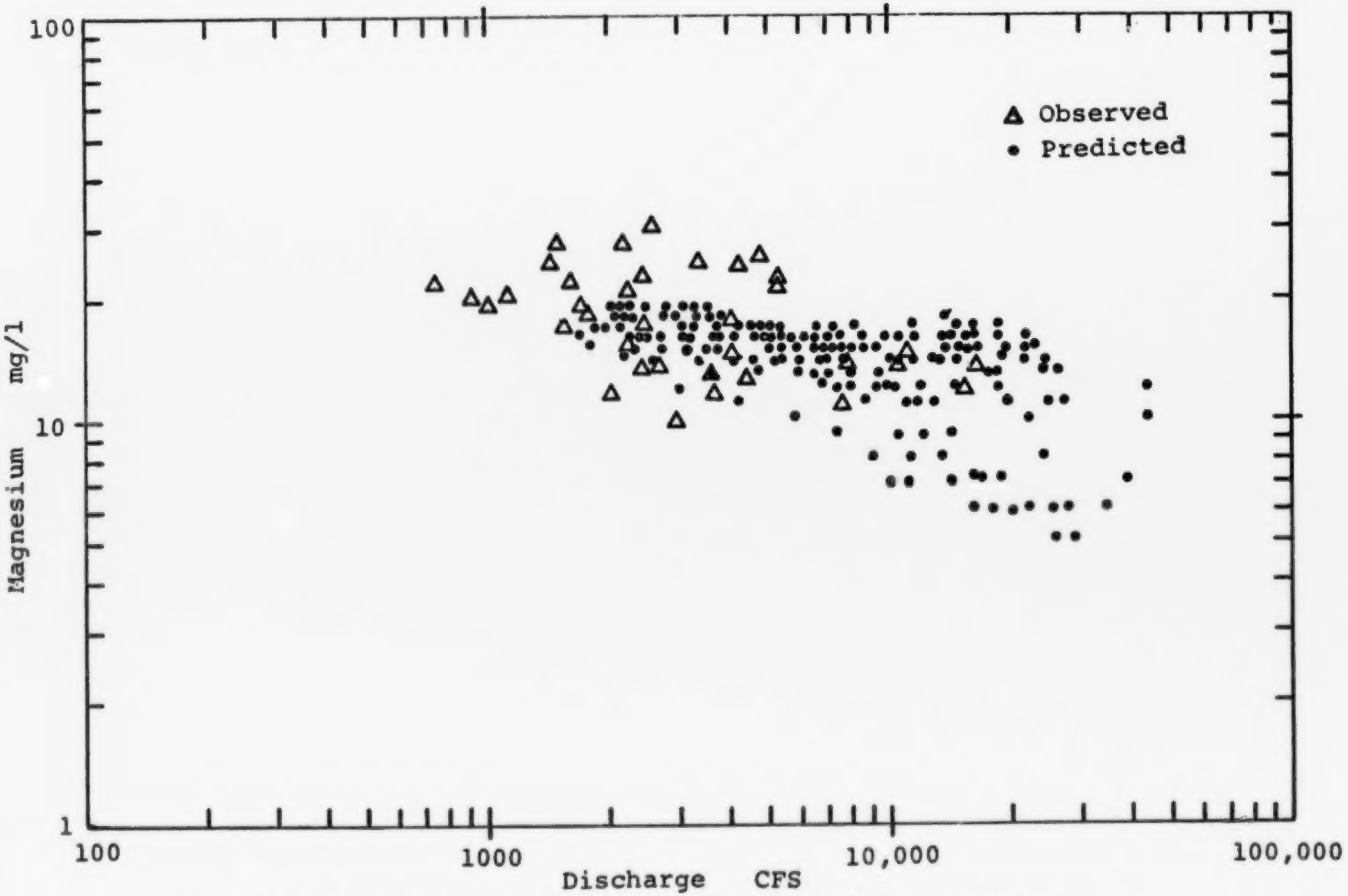


Figure 25 Observed and Predicted Magnesium Concentration as a Function of Discharge
Quality Station No 5 - Kansas River at Lecompton

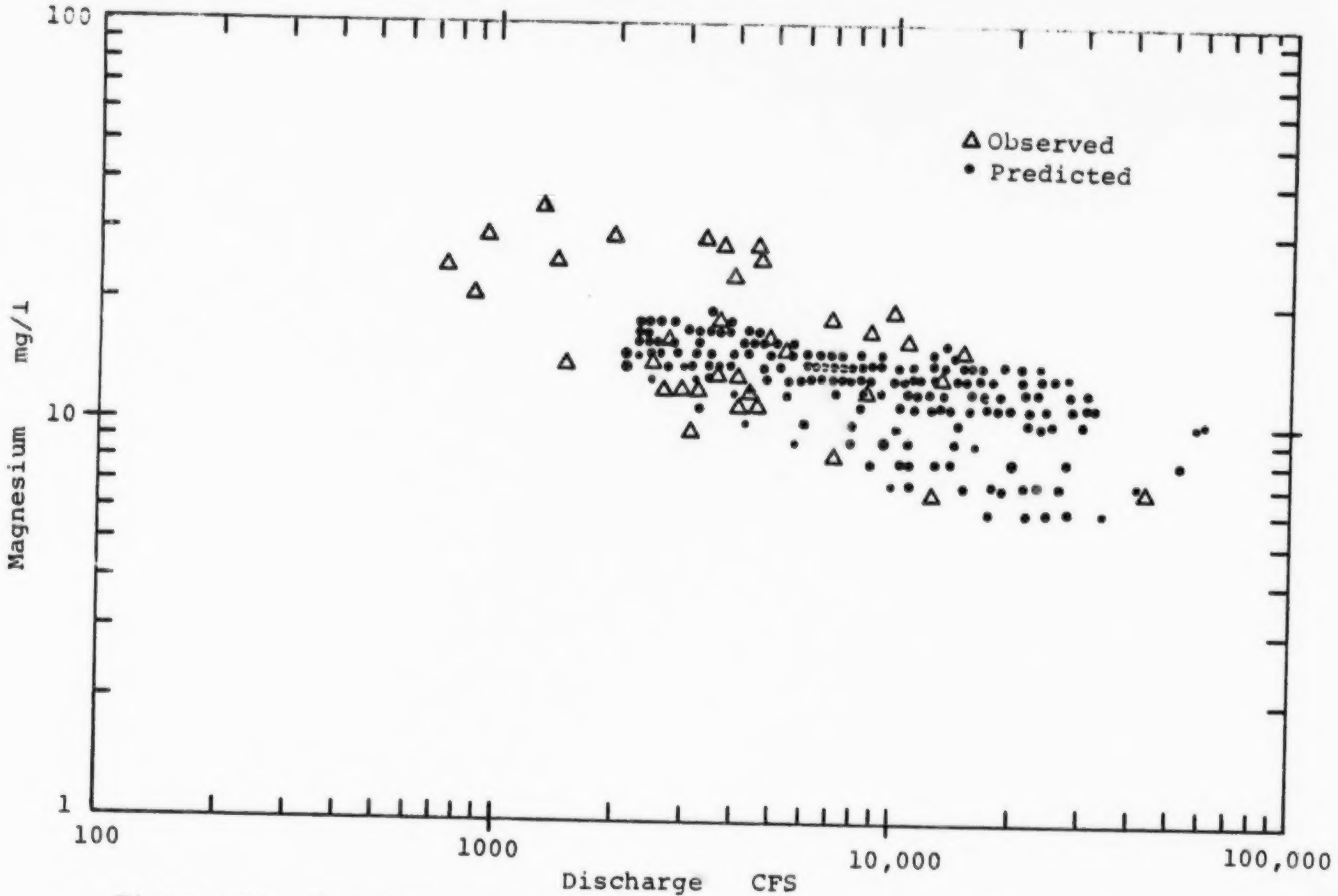


Figure 26 Observed and Predicted Magnesium Concentration as a Function of Discharge
Quality Station No 2 - Kansas River at Bonner Springs

V. Prediction of Impoundment Water Quality with Pre-Impoundment Measurements

One of the major problems involved in water quality studies is that of predicting the initial quality of water to be expected in a reservoir prior to impoundment. Stated another way we may ask, "Can the available data on the water chemistry of a stream be used to predict the approximate water composition in a reservoir."

Presently, the state of the art is essentially restricted to engineering judgement. What we have attempted to do is take the available data for the reservoirs in the Lower Kansas River Basin Model region which are currently in operation and to treat the pre-impoundment and the post-impoundment data to see if it is possible to develop an empirical approach to the problem. Admittedly, this is not quantitative, but it is an advance over present estimates.

To treat the problem, even empirically, the following assumptions must be established:

1. The historical data, if covering at least a three year period, are a fair representation of the range of water quality to be expected in a given river system the majority of the time. Extremes, owing to droughts and floods, are exceptions.
2. Reservoirs homogenize known variations in the water quality of a given stream, and thereby provide at least initially a relatively homogeneous body of water.

about the initial water quality to be expected in an impoundment.

An illustration of the method can be made by using the data for the Big Blue River near Tuttle Creek Reservoir. A ternary graph of the major cations in equivalents per million is given in Figure 27. It is obvious that Ca is the dominant cation in the water and the greatest scatter is in the preclosure samples.

The calcium in the preclosure water makes up 40-70% of the cation load. Because of the integration effects of the impoundment, a reduction in the spread of values could be expected and a 50% reduction would be reasonable. This is borne out for the cation data where the Ca content in the post-impoundment falls between 50 and 64% of the total cation load.

The anion ternary diagram for the Big Blue River at Tuttle Creek is illustrated in Figure 28. Similar reasoning to that given for computing the Ca content can be applied to the Cl, SO_4, and HCO_3 plotted on this graph.

A further preliminary check on future water quality can be obtained by examination of Σ cation vs. Σ anion graph given in Figure 29. Such plots certainly can set the limits within which the impounded waters of most systems can be expected to fall. The range for this water is 125-525 mg/L and 42-185 mg/L for the anion and cation range respectively. Applying a 50% reduction in the range figures yields limits of 225-425 ppm and 78-150 ppm for anions and cations

Figure 27

Cation Ternary Diagram for the Big Blue River Near Tuttle Creek Reservoir; Quality Station Number 9 and Quality Station Number 26.

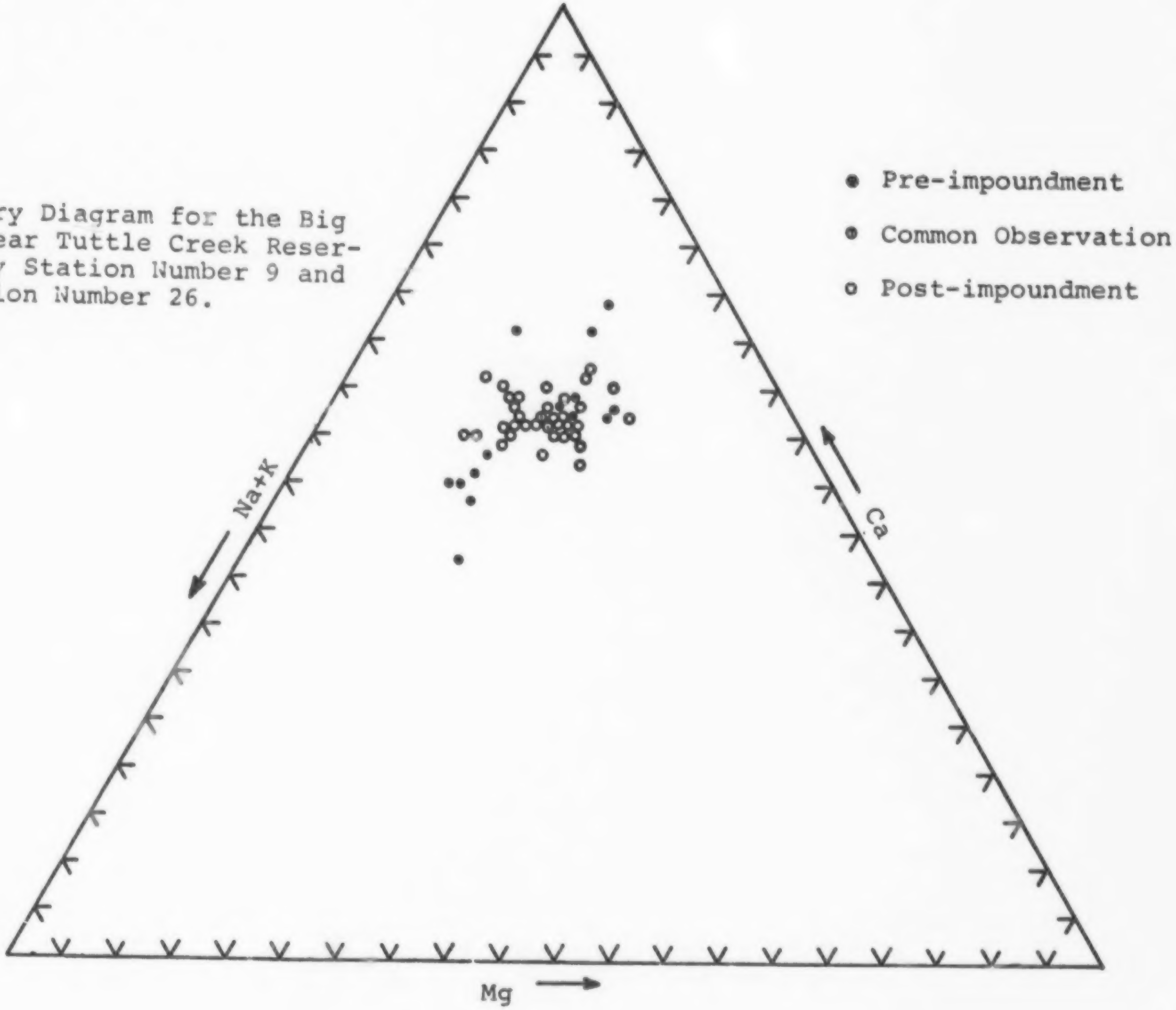
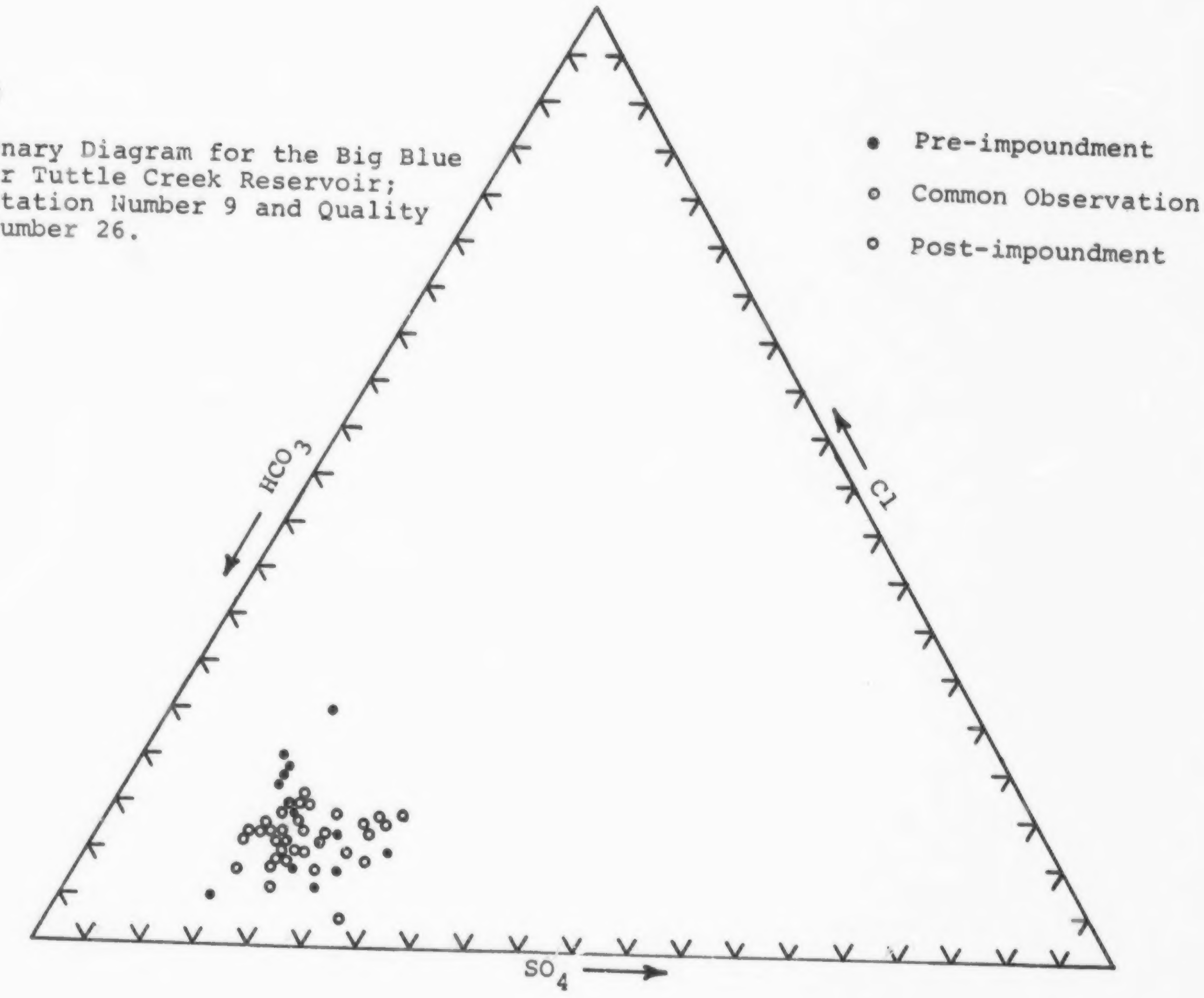


Figure 28

Anion Ternary Diagram for the Big Blue River Near Tuttle Creek Reservoir; Quality Station Number 9 and Quality Station Number 26.



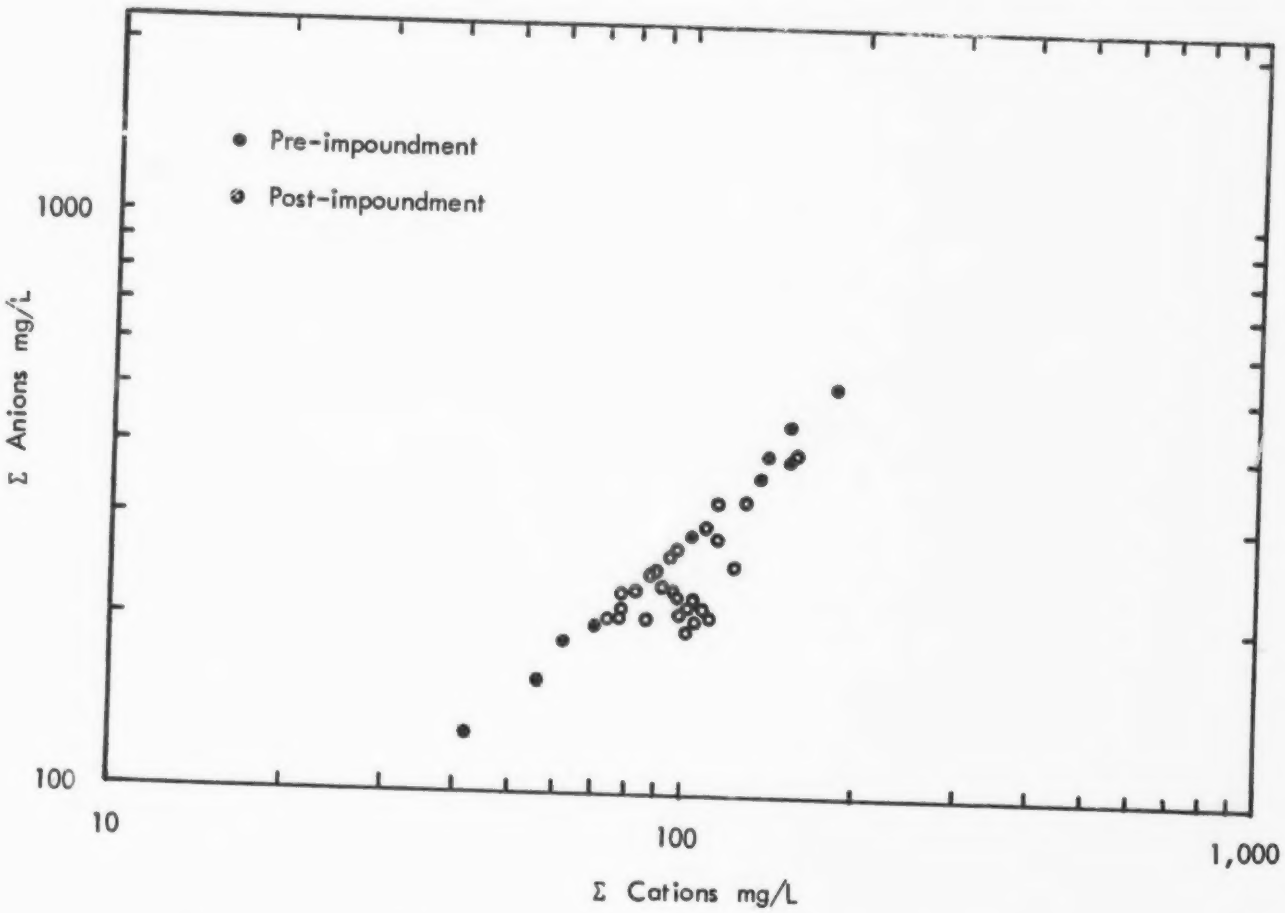


Figure 29 Σ Anions vs. Σ Cations for the Big Blue River Near Tuttle Creek Reservoir; Quality Station Number 9 and Quality Station Number 26.

respectively. Reference to Figure 29 shows such a range includes most of the data for the discharge from Tuttle Creek Reservoir. Similar results can be obtained with plots of Σ anion and Σ cation vs. specific conductivity.

The results obtained from these methods are summarized in Table 4.

A similar analysis can be conducted for Kanapolis reservoir on the Smoky Hill River. Pre-impoundment data do not exist for this site but the data for the Smoky Hill River at Ellsworth, which is immediately above the reservoir, provide an acceptable substitute. The data for this reservoir are given in Figures 30 through 32. A summary of the results obtained is given in Table 5.

The prediction for HCO_3 in Table 5 was obtained by omitting the one data point on Figure 31 at 66% HCO_3. This point definitely appears to be in error. Omitting this observation does not significantly influence the other anion limits.

The approach used in the two previous examples breaks down if the water type varies significantly with discharge. This occurs on the Saline River which is primarily a sodium chloride and sodium sulfate type water at low discharge and a calcium bicarbonate type water at peak flows (6). The ternary diagrams shown in Figures 33 and 34 for the Saline River at Russell reflect this shift in the wide scatter of the data. The scatter of the anion data is much too great to permit post-impoundment predictions, and the scatter of

Figure 30

Cation Ternary Diagram for the Smoky Hill River Above and Below Kanopolis Reservoir; Quality Station Number 28 at Ellsworth and Quality Station Number 22 at Langley.

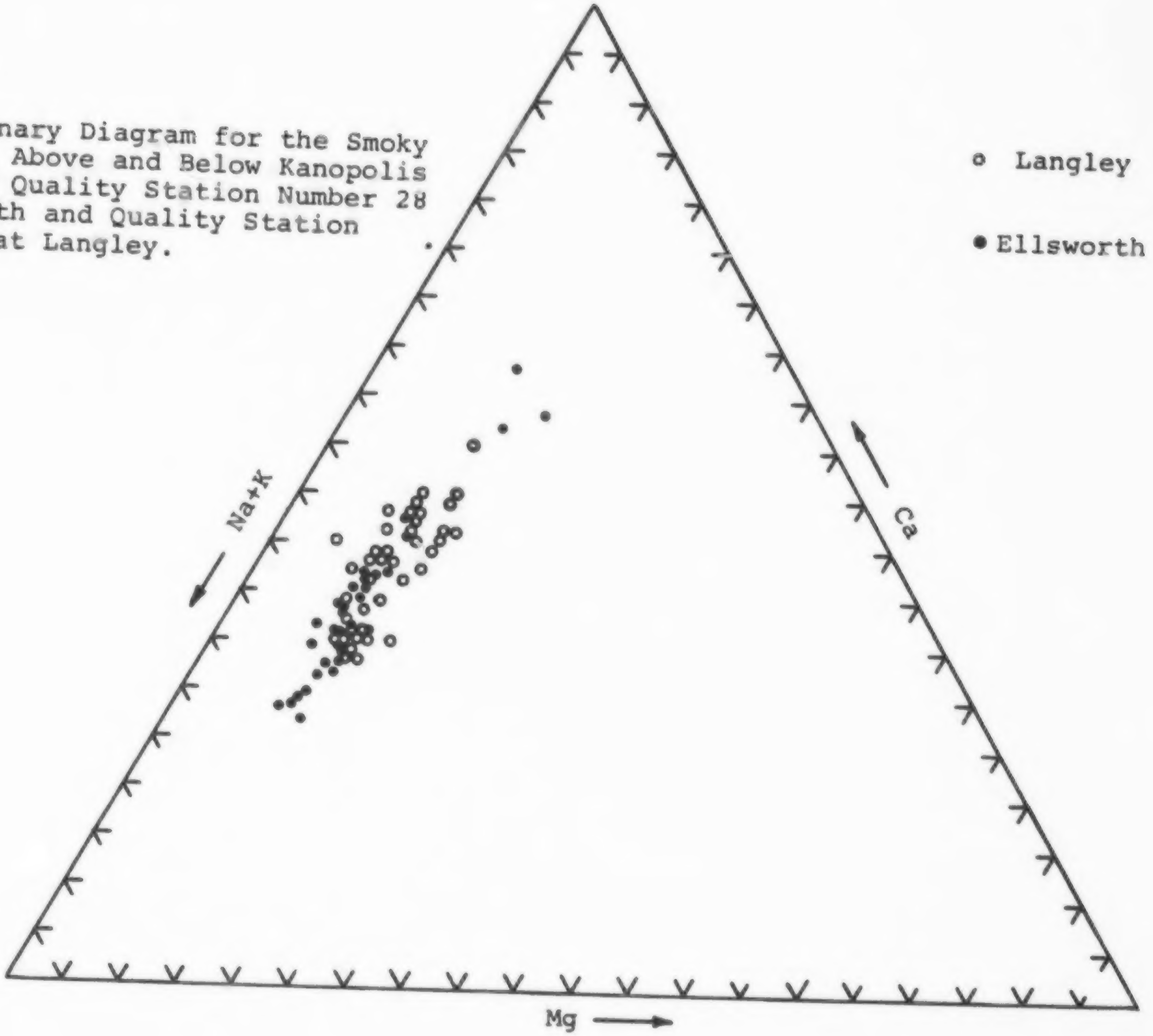
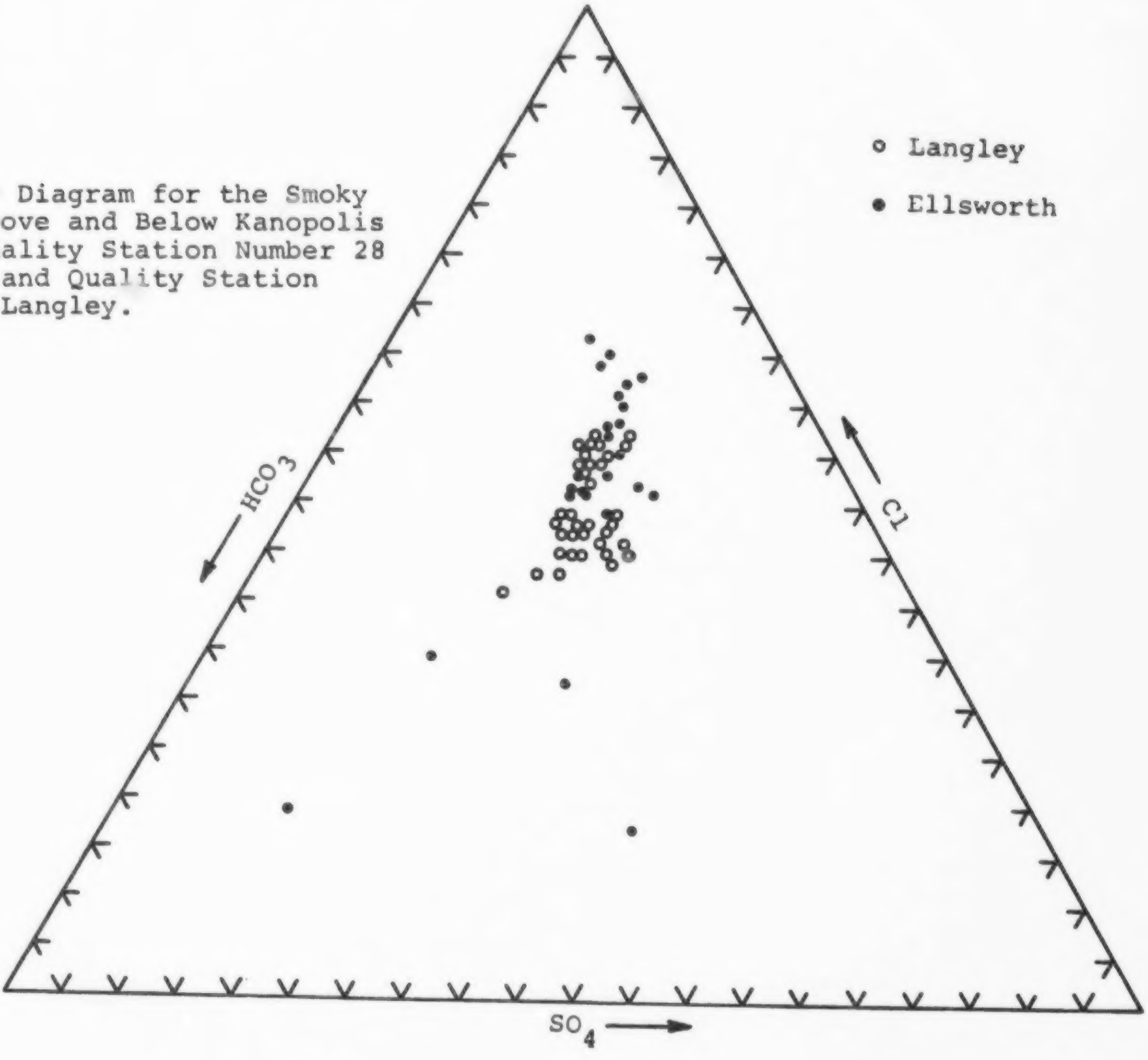


Figure 31

Anion Ternary Diagram for the Smoky Hill River Above and Below Kanopolis Reservoir; Quality Station Number 28 at Ellsworth and Quality Station Number 22 at Langley.



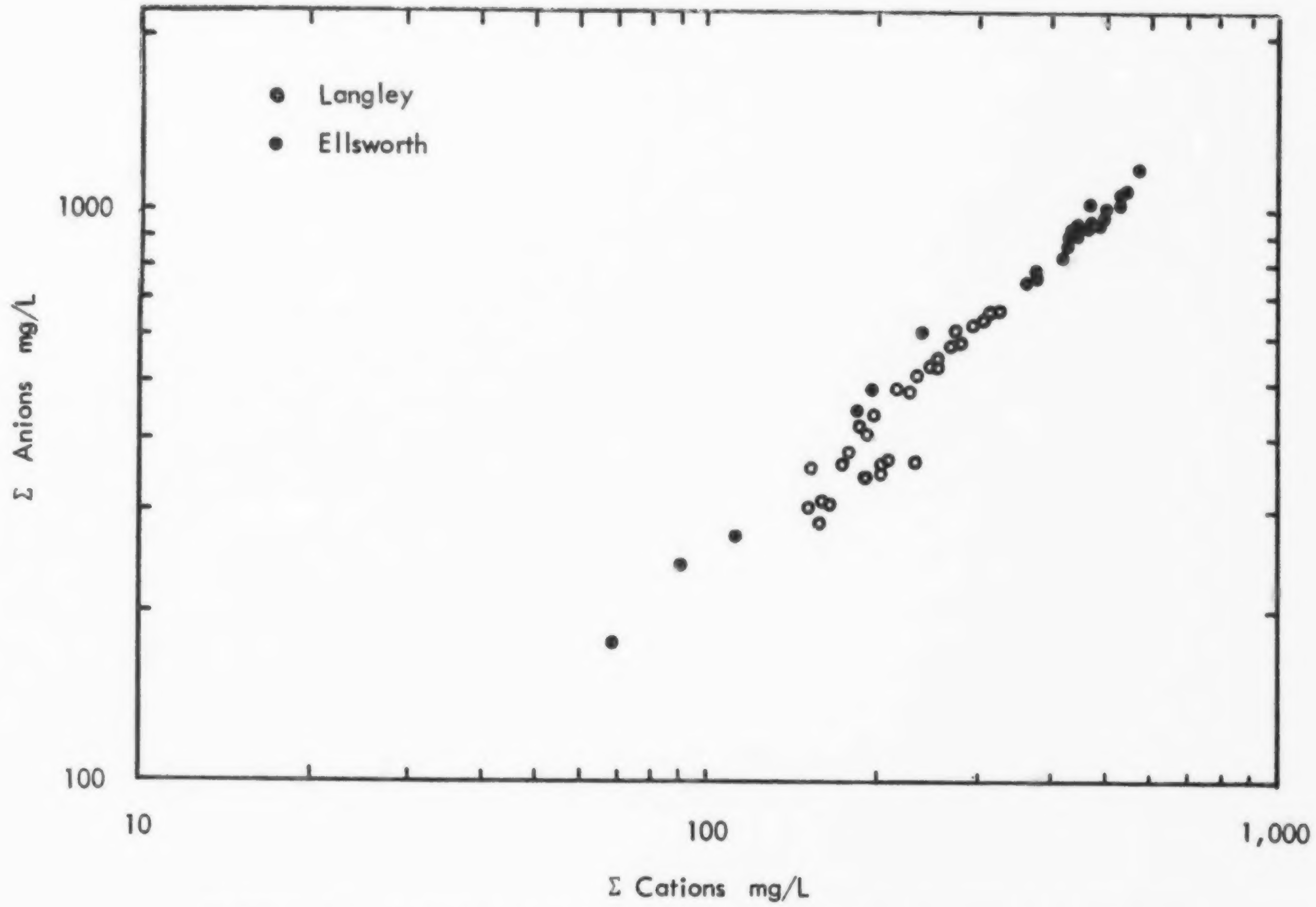


Figure 32 Σ Anions vs. Σ Cations for the Smoky Hill River Above and Below Kanopolis Reservoir; Quality Station Number 28 at Ellsworth and Quality Station Number 22 at Langley.

Table 5: Comparison of Predicted and Observed Composition Changes in the Water in Kanopolis Reservoir, Kansas.

Constituent	Range of Pre-impoundment Composition	Predicted Range of Post-impoundment Composition	Observed Range of Post-impoundment Composition
Ca	27-63%	36-54%	33-55%
Mg	8-18%	11-16%	6-16%
Na+K	24-63%	34-54%	32-55%
Cl	17-67%	29-55%	32-57%
SO_4	15-47%	23-39%	22-33%
HCO_3	13-66%	21-37%	17-36%
Anions	175-1193 mg/L	430-940 mg/L	300-700 mg/L
Cations	69-573 mg/L	195-447 mg/L	150-300 mg/L

Figure 33

Cation Ternary Diagram for the Saline River Above and Below Wilson Reservoir; Quality Station Number 23 at Russell and Quality Station Number 20 at Sylvan Grove.

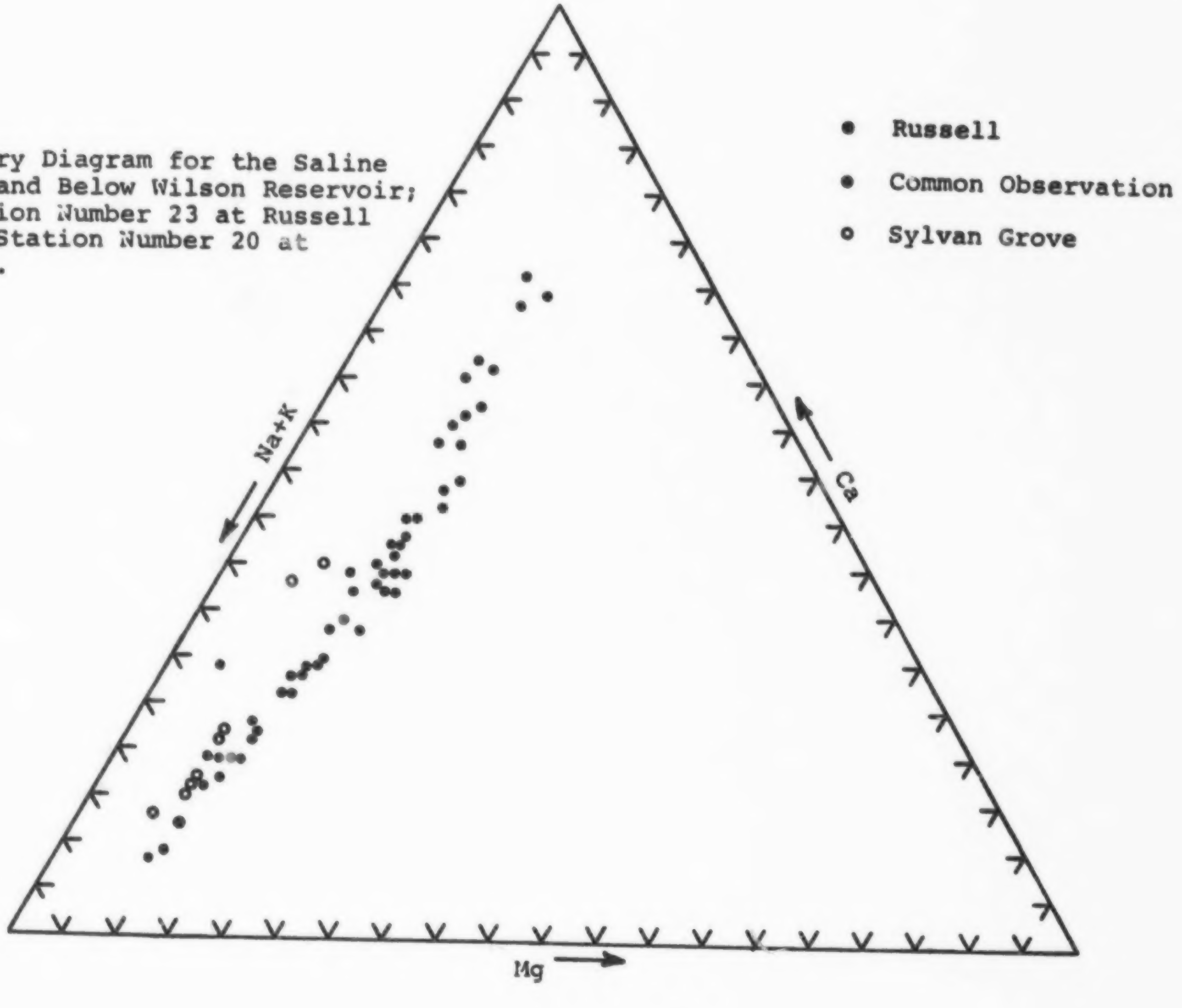
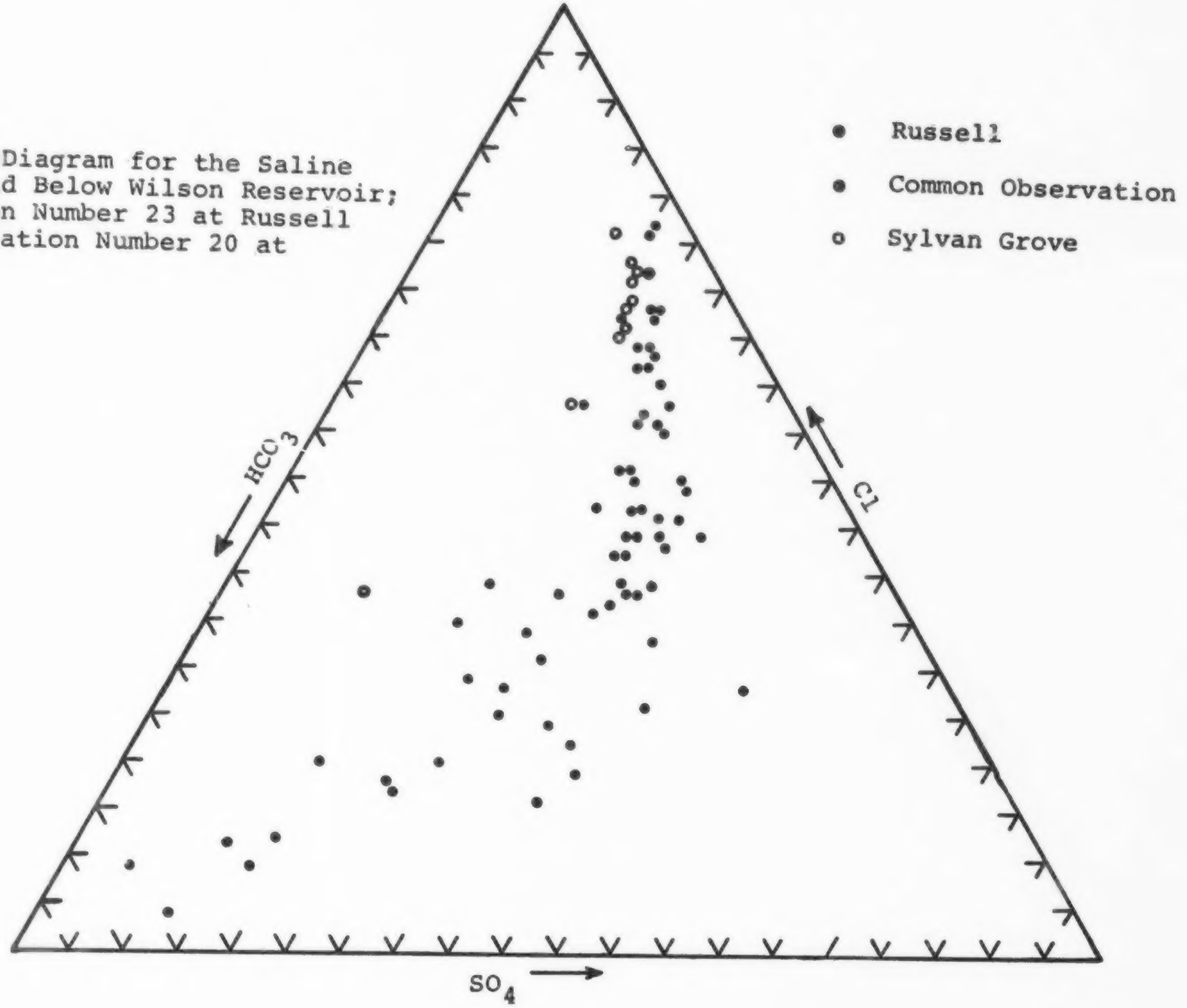


Figure 34

Anion Ternary Diagram for the Saline River Above and Below Wilson Reservoir; Quality Station Number 23 at Russell and Quality Station Number 20 at Sylvan Grove.



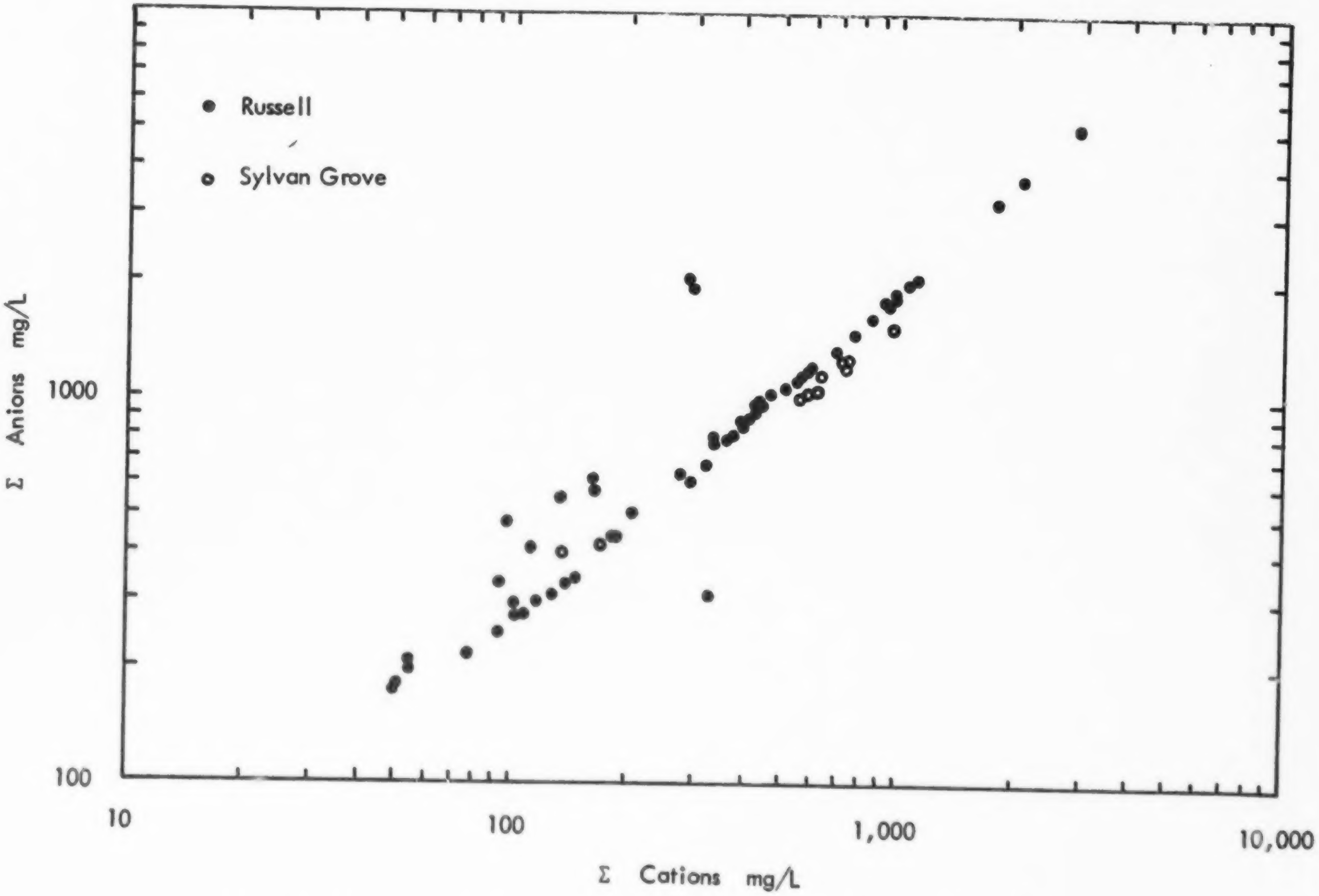


Figure 35 Σ Anions vs. Σ Cations for the Saline River Above and Below Wilson Reservoir; Quality Station Number 23 at Russell and Quality Station Number 20 at Sylvan Grove.

and to apply a 50% range reduction using these figures as midpoints. For example, the visually estimated mean for the Σ anions for the Saline River at Russell is 900 mg/L. The observed Σ anion range is 170-2000 mg/L. Using 900 mg/L as a midpoint and reducing the predicted range by 50% produces an anion range of 493-1307 mg/L. This again includes three-fourths of the data observed at Sylvan Grove.

The predicted range of the post-impoundment percentage composition of a water can be converted to a predicted concentration range by multiplying the predicted percentage range by a selected point on the observed Σ anion or Σ cation range. This point is primarily an empirical approach to account for the nongaussian distribution of flows in an unregulated river. A sample collection program using regular sample collection intervals will miss a significant percentage of the less frequent high flows and tend to skew the observed range toward the low flow observations. A reservoir integrates the continuous discharge spectrum and therefore requires a weighting factor to account for the relatively large volumes of water contributed by the high discharges. The magnitude of the factor is also influenced by the yearly hydrograph pattern, the evaporation loss in the reservoir and the reservoir operating policy.

The point of best fit for Tuttle Creek Reservoir was observed to be the one-fourth point from the top of the observed Σ anion and Σ cation range. The one-third point of the observed range produced the most satisfactory results at Kanopolis Reservoir. In both instances the exact magnitude of the selected point is not critical in establishing the basis for the method. It is significant to note, however, that the points of best fit shifted between these two reservoirs in the direction that would be expected from a consideration of the expected evaporation losses.

As illustrated in Tables 6 and 7, the predicted concentration range of the individual dissolved ions in the reservoir discharges include the bulk of the observed data in all cases except calcium at Tuttle Creek Reservoir and magnesium at Kanopolis Reservoir. The under prediction of the observed calcium concentration range at Tuttle Creek Reservoir may indicate that calcium carbonate is coming into solution from the walls of the reservoir. If this is the case, one of the basic assumptions of the method has been violated. The over prediction of the magnesium concentration in the discharge from Kanopolis Reservoir probably illustrates one of the inherent weaknesses of the method in that magnesium is a relatively minor constituent of this water and is, therefore, much more sensitive to small discrepancies in analysis of the data.

The predictive method is conservative in that the majority of observations that are outside the predicted range of concentrations fall below the predicted values. Also implicit in the predictive method is the assumption that the concentration of the dissolved ions in the reservoir outflow is independent of discharge. The regression equations presented in

Table 6: Predicted and Observed Dissolved Ion Concentrations in the Discharge from Tuttle Creek Reservoir, Kansas.

1/4 point of observed range Σ anion 225 mg/L Σ cation 78 mg/L					
Dissolved Ion	Predicted Concentration Range mg/L	Observed Concentration Range mg/L	Number of Observations	Observations Above Predicted Range	Observations Below Predicted Range
Ca	40-49	39-87	42	30	1
Mg	9-22	6-25	42	1	4
Cl	16-36	9-29	42	0	8
SO_4	36-54	25-99	42	4	15

Table 7 Predicted and Observed Dissolved Ion Concentrations in the Discharge from Kanopolis Reservoir, Kansas.

1/3 point of observed range Σ anion 510 mg/L Σ cation 235 mg/L					
Dissolved Ion	Predicted Concentration Range mg/L	Observed Concentration Range mg/L	Number of Observations	Observations Above Predicted Range	Observations Below Predicted Range
Ca	85-127	66-128	49	1	9
Mg	26-38	8-28	49	0	47
Cl	148-281	104-308	49	2	12
SO_4	117-199	77-193	49	0	10

Table 2 indicate that this is essentially true in the case of a large reservoir like Tuttle Creek, but that a small reservoir like Kanopolis does exhibit a consistant lowering of dissolved ion concentration as the discharge is increased. The predictive method is, therefore, most applicable in reservoirs like Kanopolis during critical low-flow augmentation periods.

The methods illustrated above can be used to develop predictions for the water quality which can be expected in Glen Elder, Milford and Perry Reservoirs. The pre-impoundment data used in developing predictions for Glen Elder Reservoir were from quality stations 18 and 24. The one-third point of the observed Σ anion and Σ cation range was used to compute the predicted concentration ranges. The results are summarized in Table 8.

The predicted magnesium concentration range for Glen Elder Reservoir is probably high for the same reason that the Kanopolis Reservoir prediction was higher than the observed concentration.

Quality stations 11 and 25 were used in developing predictions for Milford Reservoir. The one-fourth points of the observed Σ anion and Σ cation ranges were used to compute the predicted concentration ranges. The results are summarized in Table 9.

The predictions for Perry Reservoir are based on the data from quality stations 7 and 27. The one-fourth points of the observed Σ anion and Σ cation ranges were used to compute the

Table 8: Predicted Percentage Composition and Dissolved Ion Concentration Range for Glen Elder Reservoir, Kansas.

Constituent	Observed Range of Pre-impoundment Composition	Predicted Range of Post-impoundment Composition	Predicted Range of Post-impoundment Concentration
Ca	40-67%	47-60%	108-137 mg/L
Mg	10-19%	12-17%	27-39 mg/L
Cl	11-31%	15-25%	76-126 mg/L
SO_4	29-44%	32-40%	162-202 mg/L
Σ Anion	300-920 mg/L	455-765 mg/L	
Σ Cation	120-450 mg/L	283-367 mg/L	

Table 9: Predicted Percentage Composition and Dissolved Ion Concentration Range for Milford Reservoir, Kansas.

Constituent	Observed Range of Pre-impoundment Composition	Predicted Range of Post-impoundment Composition	Predicted Range of Post-impoundment Concentration
Ca	40-63%	46-58%	51-64 mg/L
Mg	10-28%	14-24%	16-27 mg/L
Cl	7-32%	13-25%	35-68 mg/L
SO_4	18-31%	21-28%	57-76 mg/L
Σ Anion	140-660 mg/L	270-530 mg/L	
Σ Cation	58-270 mg/L	111-217 mg/L	

predicted concentration ranges. Table 10 summarizes the results.

The predicted ranges for the calcium concentration in both Milford and Perry Reservoirs are probably low, as these waters can be expected to become saturated in $CaCO_3$ by solution from the walls of the impoundments.

The empirical methods suggested for predicting water quality in an impoundment from pre-impoundment measurements are admittedly crude. They do represent a step forward from the present state of the art, however, and should be explored further to determine their range of applicability. It is, therefore, suggested that consideration be given to the location or relocation of water quality sampling stations below the outlets of the reservoirs in the region as the new structures are completed. The water quality in Wilson Reservoir also deserves special study to determine if an approach can be developed to account for the change in water type that occurs with varying discharge in the Saline River.

Table 10: Predicted Percentage Composition and Dissolved Ion Concentration Range for Perry Reservoir, Kansas.

Constituent	Observed Range of Pre-impoundment Composition	Predicted Range of Post-impoundment Composition	Predicted Range of Post-impoundment Concentration
Ca	54-72%	58-68%	39-46 mg/L
Mg	14-40%	20-34%	13-23 mg/L
Cl	4-16%	7-13%	13-25 mg/L
SO_4	7-28%	13-23%	25-44 mg/L
Anion	88-500 mg/L	191-397 mg/L	
Cation	32-170 mg/L	67-136 mg/L	

VI. Non-Conservative Water Quality

The Kansas State Department of Health collected and analyzed water samples throughout the area included in the Lower Kansas River Basin Model from June 1966 through May 1967. Samples were collected weekly from water quality stations 1 through 22 from June 13, 1966 through August 29, 1966. Samples were collected twice monthly throughout the remainder of the period from stations 2, 5, 7, 8, 9, 11, 13, 18, 20, and 22. A compilation of the non-conservative parameters calculated from the data obtained by this program is presented in Appendix C. A pictorial summary of the data is given in Figures 36 through 41. The numerical values given in these Figures are suitable for use in the model when it is being used to evaluate the impact of non-conservative pollutants on the river network in the lower basin.

"Summer" is defined in these figures as June, July and August. The remaining nine months are designated "fall through spring."

All of the sample analyses conducted by the Kansas State Health Department were performed in accordance with the procedures set forth in the twelfth edition of Standard Methods (7). Nitrification suppression techniques were not employed in the biochemical oxygen demand tests. The deoxygenation rate constants computed from these tests indicate that in some cases nitrification was undoubtedly occurring. To compensate for this, all computed deoxygenation rate constants of less than 0.08 were excluded from the values used in developing

Figures 36 and 37. The deoxygenation rate constants and the ultimate biochemical oxygen demand were computed from three and six-day observations by the method developed by Rhame (8).

The dissolved-oxygen percent saturation values given in Figures 40 and 41 were computed by comparing observed values of dissolved oxygen with standard dissolved oxygen saturation values (9). These standard values were adjusted to account for the decrease in solubility due to the reduction in the observed pressures below the standard sea level value by averaging the average monthly barometric pressures for the years 1959 through 1963 from the published records of the U. S. Weather Bureau for the stations at Kansas City, Missouri; Topeka, Kansas and Concordia, Kansas. The Kansas City and Topeka pressures were averaged and applied to that portion of the model region east of quality station 12 at Junction City, Kansas. The Concordia pressure pattern was applied to that portion of the model area west of Junction City. The average barometric pressure east of Junction City was 736 millimeters of mercury while the average pressure west of this point was 724 millimeters of mercury. The seasonal variation in pressure was not significant in either area. The dissolved oxygen saturation values for both regions are given in Tables 11 and 12.

The results obtained in Figures 40 and 41 were influenced somewhat by altering the dissolved oxygen saturation values from one end of the model area to the other. This degree of refinement is not realistic, however, when using the lower

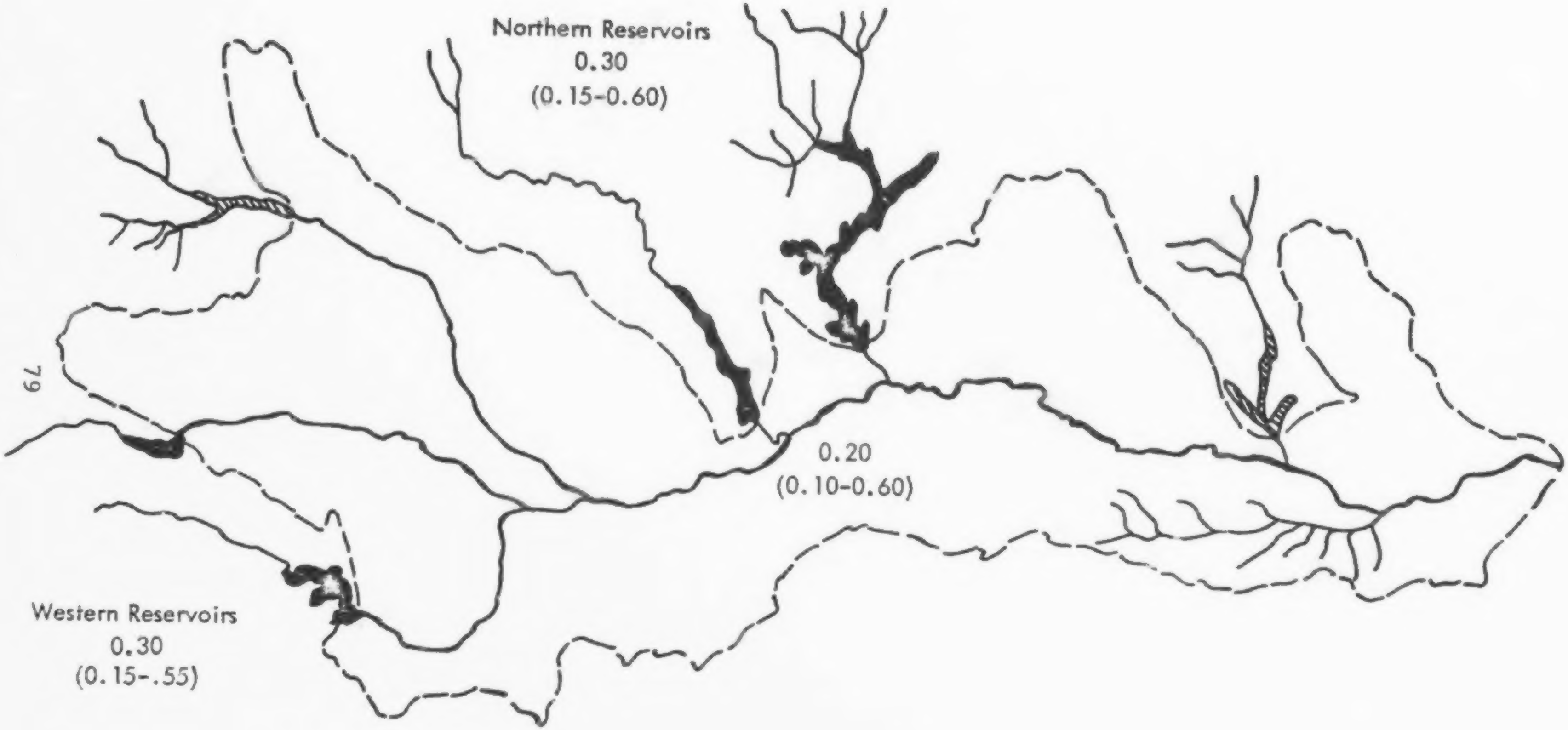

Northern Reservoirs
0.30
(0.15-0.60)
0.20
(0.10-0.60)
Western Reservoirs
0.30
(0.15-.55)

Figure 36 Average and Range of the Deoxygenation Rate Constant (K_1/Day 20°C base e) in the lower Kansas River Basin During Fall Through Spring Low Flow Conditions.

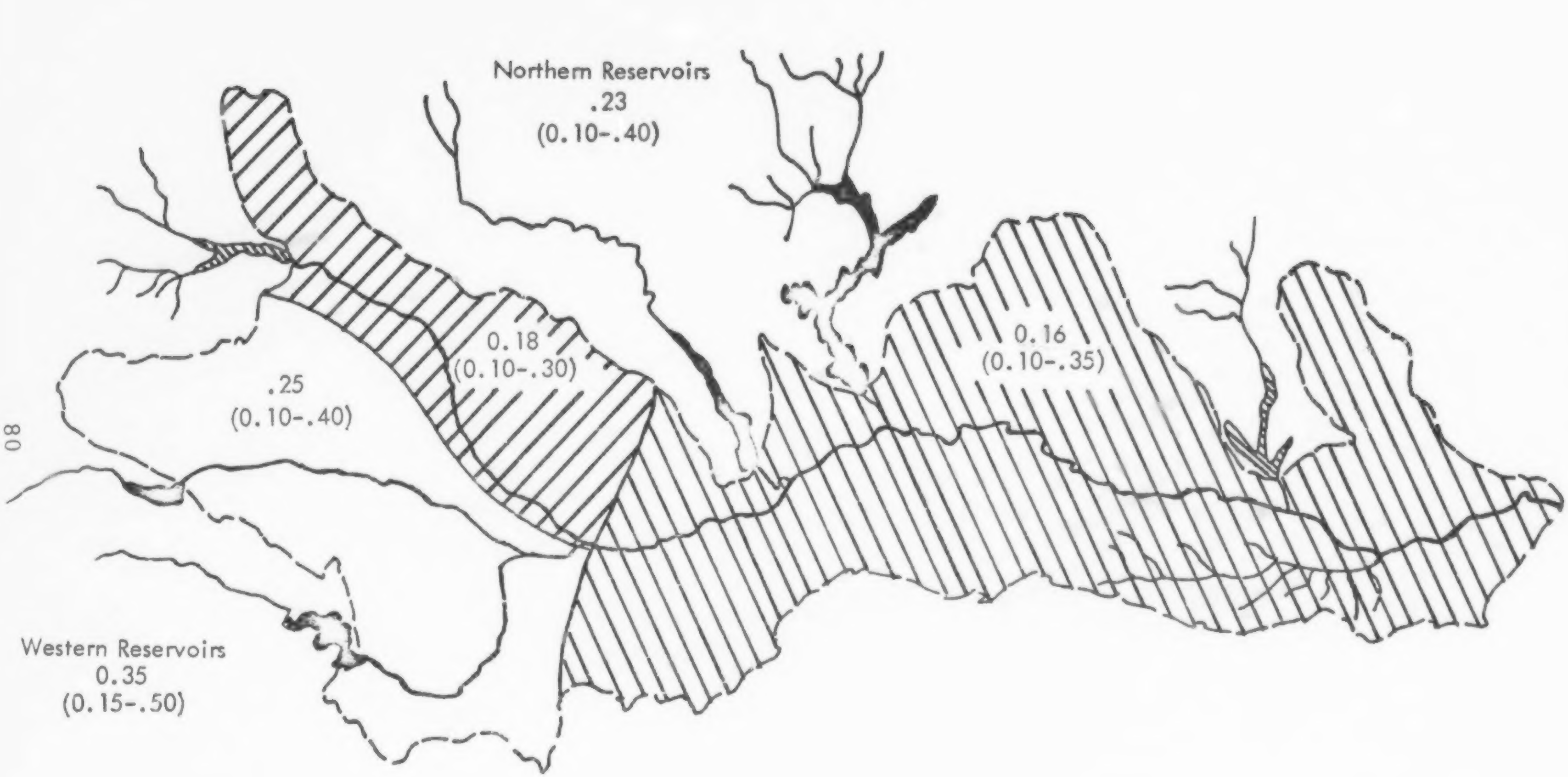

Northern Reservoirs
.23
(0.10-.40)
0.18
(0.10-.30)
.25
(0.10-.40)
0.16
(0.10-.35)
Western Reservoirs
0.35
(0.15-.50)

Figure 37 Average and Range of the Deoxygenation Rate Constant (K_1/Day 20°C base e) in the Lower Kansas River Basin During Summer Low Flow Conditions.

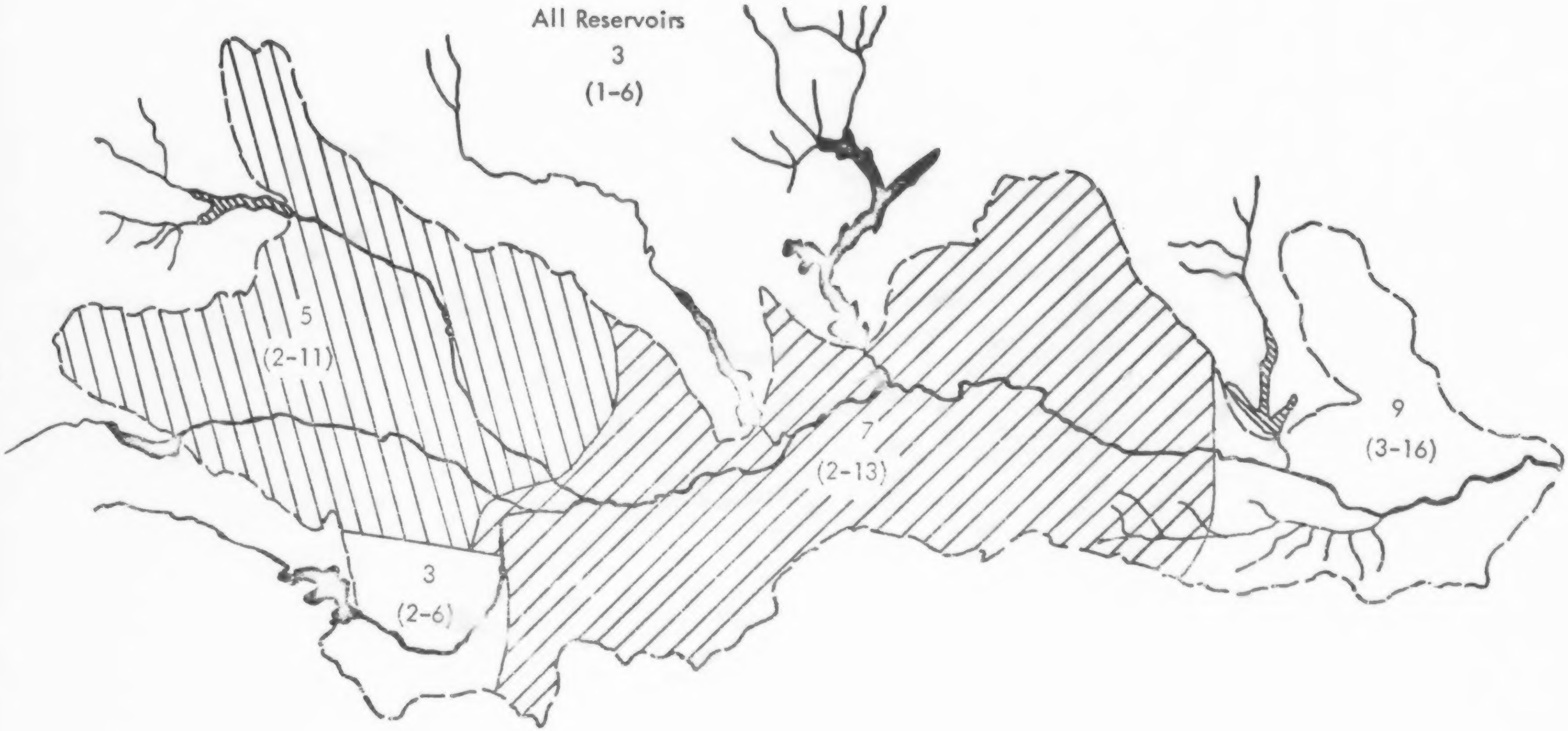

All Reservoirs
3
(1-6)
5
(2-11)
3
(2-6)
7
(2-13)
9
(3-16)

Figure 38 Average and Range of the Ultimate Biochemical Oxygen Demand (L_1 in mg/L) in the Lower Kansas River Basin During Fall through Spring Low Flow Conditions.

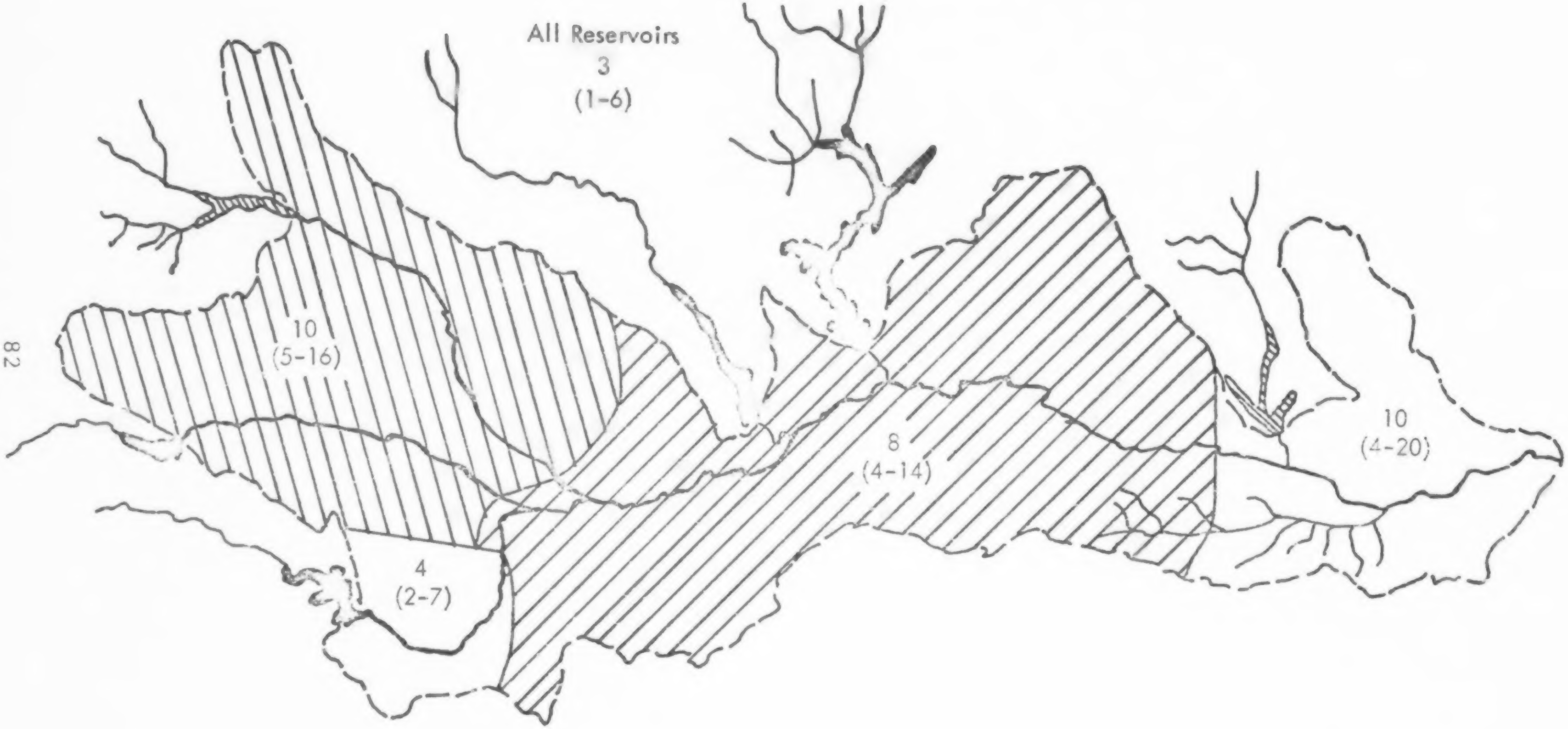

All Reservoirs
3
(1-6)
10
(5-16)
4
(2-7)
8
(4-14)
10
(4-20)

Figure 39 Average and Range of the Ultimate Biochemical Oxygen Demand (L_1 in mg/L) in the Lower Kansas River Basin During Summer Flow Conditions.

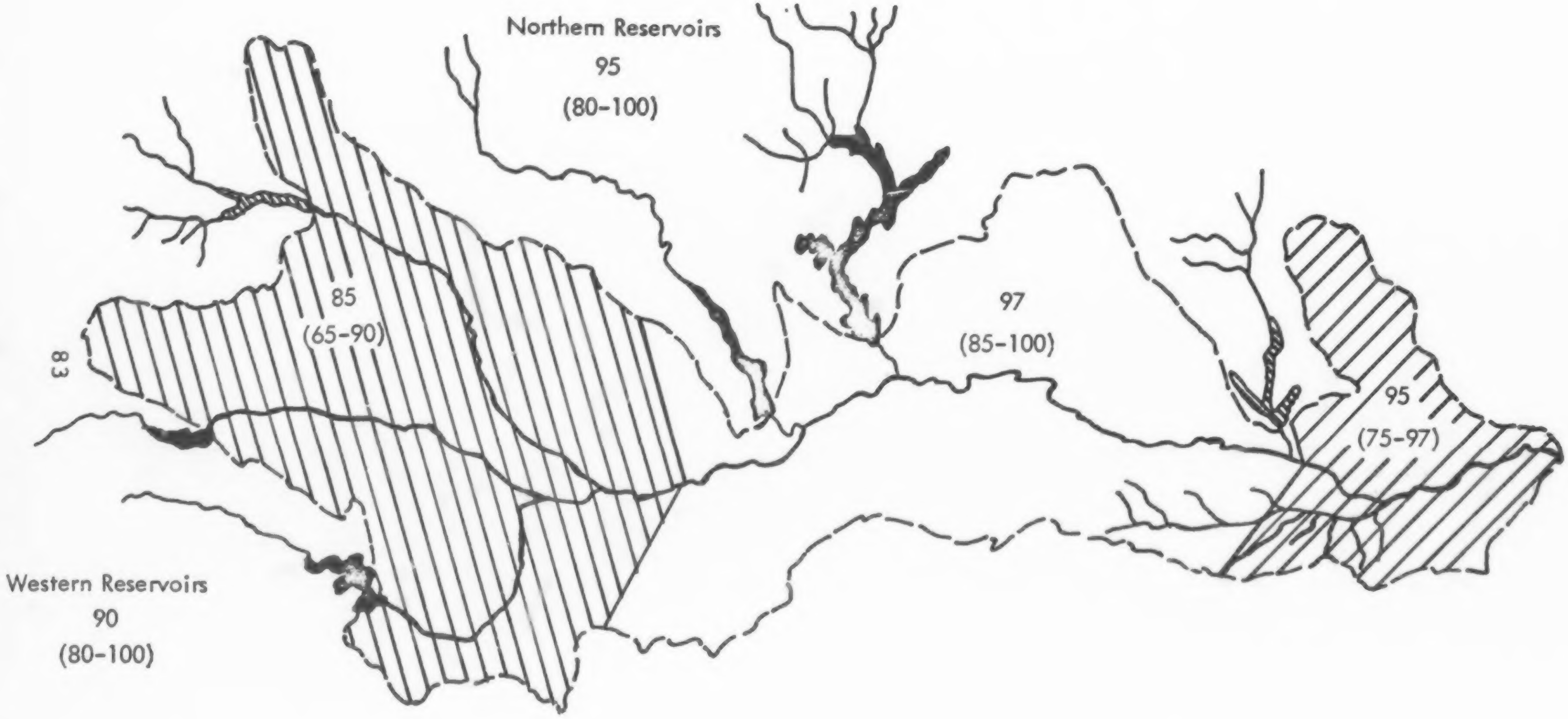

Northern Reservoirs
95
(80-100)
85
(65-90)
97
(85-100)
95
(75-97)
Western Reservoirs
90
(80-100)

Figure 40 Average and Range of the Percent Saturation of Dissolved Oxygen in the Lower Kansas River Basin During Fall through Spring Low Flow Conditions.

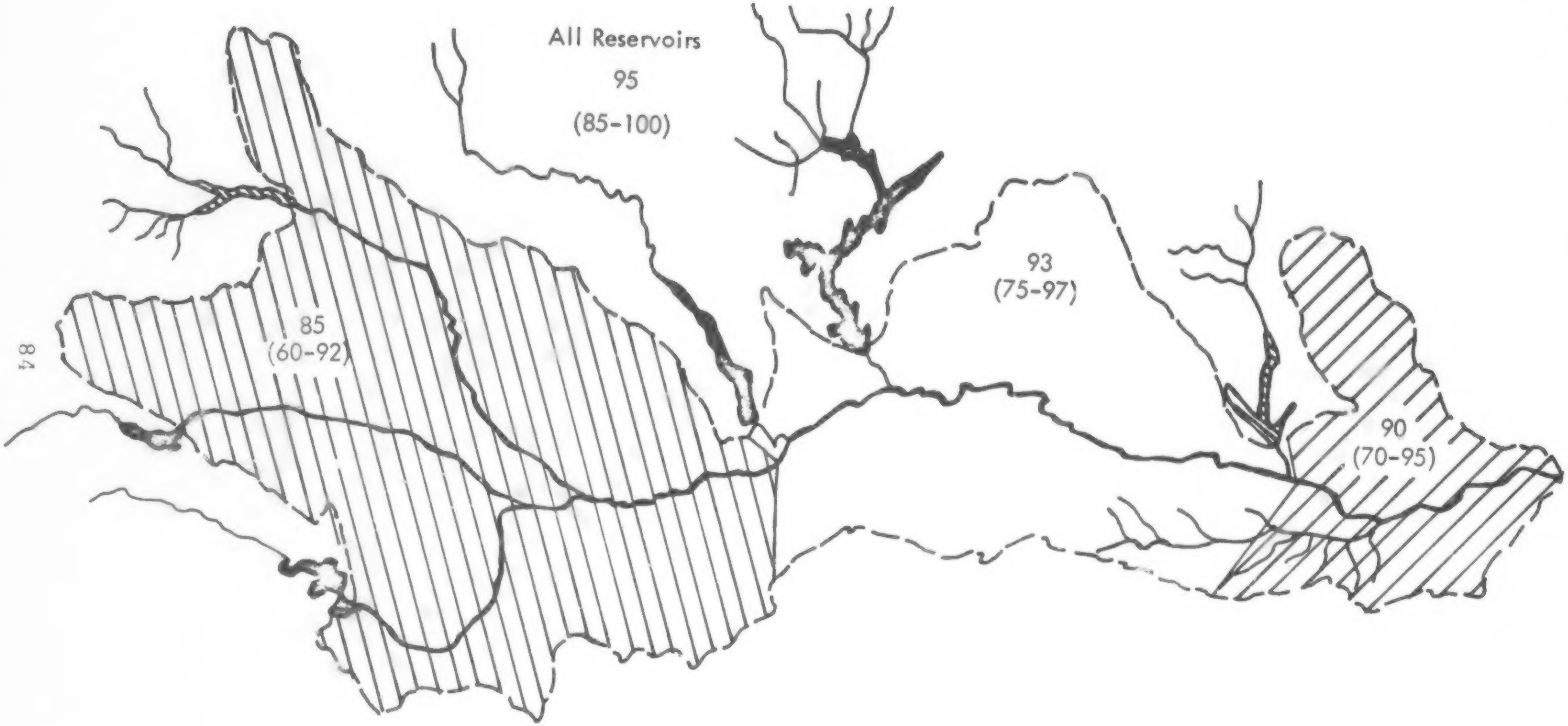

All Reservoirs
95
(85-100)
93
(75-97)
85
(60-92)
90
(70-95)

Figure 41 Average and Range of the Percent Saturation of Dissolved Oxygen in the Lower Kansas River Basin During Summer Low Flow Conditions.

Table 11: Dissolved-Oxygen Saturation Values for that Portion of the Lower Kansas River Basin Model Area East of Junction City, Kansas.

Temperature °C	Dissolved Oxygen mg/L	Temperature °C	Dissolved Oxygen mg/L	Temperature °C	Dissolved Oxygen mg/L
0	14.2	12	10.4	24	8.0
1	13.8	13	10.2	25	7.9
2	13.4	14	9.9	26	7.7
3	13.0	15	9.7	27	7.6
4	12.7	16	9.5	28	7.5
5	12.4	17	9.3	29	7.3
6	12.0	18	9.1	30	7.2
7	11.7	19	8.9	31	7.2
8	11.4	20	8.7	32	7.1
9	11.2	21	8.5	33	7.0
10	10.9	22	8.4	34	6.9
11	10.6	23	8.2	35	6.5

Table 12: Dissolved Oxygen Saturation Values for that Portion of the Lower Kansas River Basin Model Area West of Junction City, Kansas.

Temperature °C	Dissolved Oxygen mg/L	Temperature °C	Dissolved Oxygen mg/L	Temperature °C	Dissolved Oxygen mg/L
0	13.9	12	10.2	24	7.9
1	13.6	13	10.0	25	7.8
2	13.2	14	9.8	26	7.6
3	12.8	15	9.5	27	7.5
4	12.5	16	9.3	28	7.3
5	12.2	17	9.1	29	7.2
6	11.9	18	8.9	30	7.1
7	11.6	19	8.8	31	7.1
8	11.3	20	8.6	32	7.0
9	11.0	21	8.4	33	6.9
10	10.7	22	8.2	34	6.8
11	10.5	23	8.1	35	6.4

that the influence of photo-synthesis should be evaluated when monitoring dissolved-oxygen levels in all of the rivers in the lower basin, except possibly the Smoky Hill River below Kanopolis Reservoir and above Mentor. This is especially pertinent for the Saline River, the Solomon River, and Salt Creek.

The limited amount of photo-synthetic action in the reservoirs appears to be due to the low level of soluble phosphate available to the algae. The critical level of 0.03 mg/L phosphate as PO4 cited by Sawyer (10) was slightly exceeded only periodically in Tuttle Creek and Kanopolis Reservoirs during the summer of 1966 (5). The level of soluble phosphate in the river system was significantly above this threshold level almost all of the time. This was undoubtedly primarily due to the discharge of municipal sewage effluents into the rivers.

The location of most of the water quality sampling stations used in the 1966-1967 survey was upstream of any immediately adjacent municipal or industrial waste-water outfalls. The effects of these types of waste on the values given in Figures 40 through 41 are therefore minimal, except for the phosphate contribution mentioned earlier. The major source of the biodegradable material indicated in these Figures is runoff from agricultural land. The concentration of organic material in this runoff is significant. However, as indicated by the small deoxygenation rate constants, the material is stabilized slowly.

A new equation for computing the reaeration rate constant has been published by Langbein and Durum (11) since the preparation of the earlier report (1). These authors have combined the data of earlier investigations to produce a relationship of the form: $k2 = 3.3\ V/H^{1.33}$

Where: $k2$ = reaeration coefficient (base 10) per day,

V = average velocity in feet per second, and

H = mean depth in feet

When applied to the rivers in the lower Kansas River Basin, the Langbein-Durum equation produces values for the reaeration rate constant that are greater at high discharges and smaller at low discharges than the reaeration rate constants computed with the equations of O'Conner-Dobbins (12), Churchill et al (13) or Owens et al (14). The Langbein-Durum equation produces values of the reaeration rate constant that are consistently greater than and roughly parallel to the values generated by the equation developed by Dobbins (15). The relative magnitude of the values of the reaeration rate coefficients calculated by the various methods is illustrated in Figure 42.

One of the recommendations in the original report (1) was that the reaeration rate constant be experimentally determined for Kansas streams. Attempts to do this have been unsuccessful. The Dobbins equation, which consistently produces the most conservative evaluation of the reaeration rate constant, is being used in the Lower Kansas River Model at the present time. It is recommended that either the Dobbins equation or the

Langbein-Durum equation be used in the model until experimental measurements on the reaeration rates of relatively shallow alluvial streams are available to test the various relationships that have been proposed.

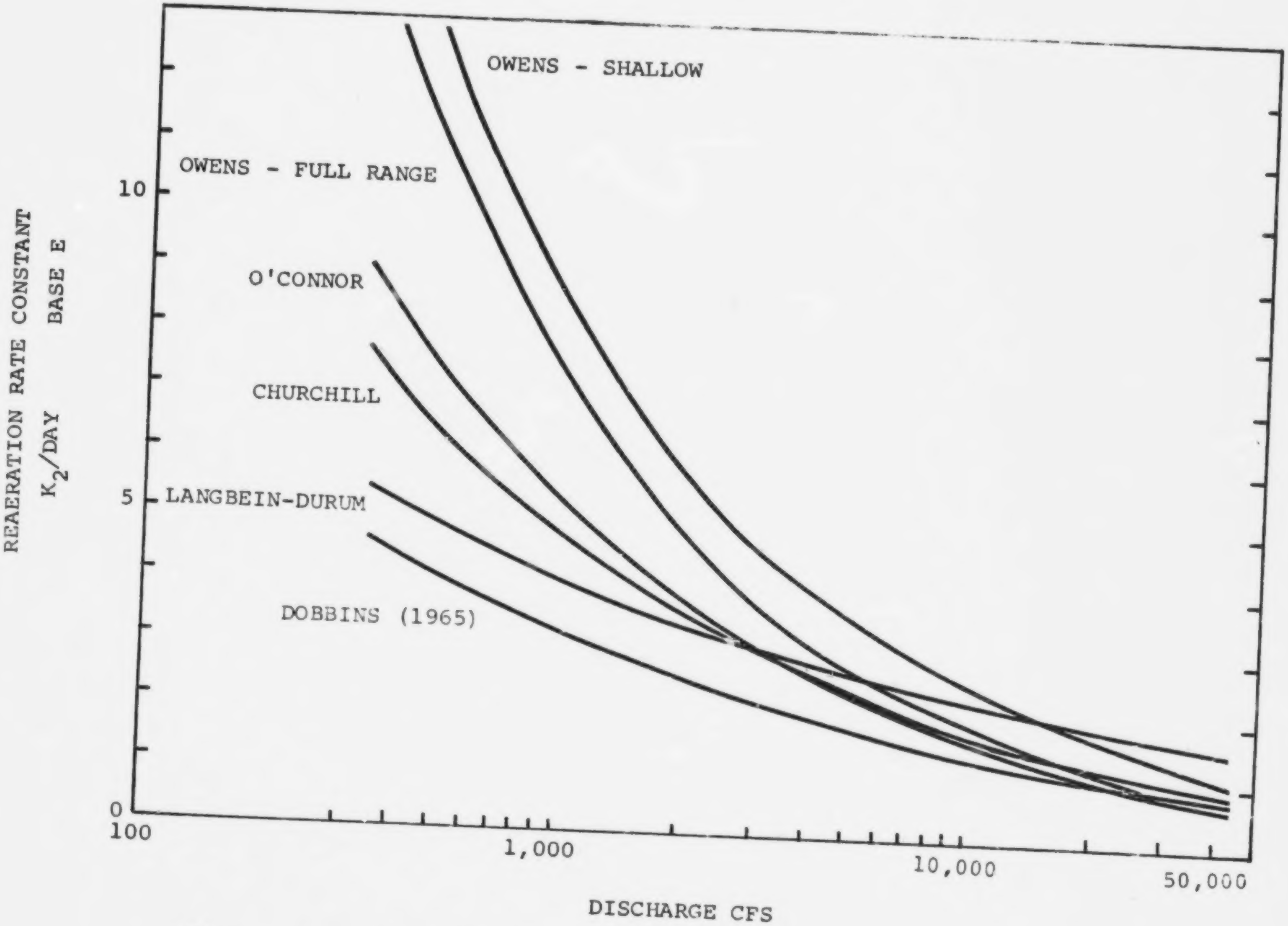


Figure 42 Computed Reaeration Coefficients as a Function of Discharge for the Kansas River at Topeka.

VII. Water Temperature

The water temperature of a stream is one of its most significant variables because most of the chemical and biological reactions which influence the water quality are temperature dependent. The U. S. Geological Survey has measured daily water temperatures at five stations in the Lower Kansas River Basin. These are:

Quality Station 2, The Kansas River at Bonner Springs;
Quality Station 8, The Kansas River at Wamego;
Quality Station 13, The Smoky Hill River at Enterprise;
Quality Station 14, The Smoky Hill River at New Cambria; and
Quality Station 16, The Solomon River at Niles.

The average monthly temperatures reported at four of these stations have been analyzed to determine the cyclic pattern and magnitude of temperature variation which can be expected. The stations and the water years of the records used are summarized in Table 13. The designation "C" in the Table indicates a complete record was available. The designation "P" indicates the record was only partially complete.

An examination of all of the monthly temperatures available at stations 8 and 13 indicated that the magnitude of these temperatures varied appreciably from year to year. Average temperatures were, therefore, computed for each month and these averages fitted to the empirical sine equation suggest by Ward (16). The form of the equation used was:

Table 13:

Water Temperature Records Analyzed to Determine the Cyclic Pattern and Magnitude of Temperature to be Expected in the Lower Kansas River Basin.

Station	1956	1957	1958	1959	1960	1961	1962	1963	1964
2 8 13 16	C	C C	C C	P P	P P	P P	C C C C	C P C C	P C C

Table 14:

Summary of Temperature Analyses for the Lower Kansas River Basin.

Station Number	A - °F	C degrees	$\overline{T}$ - °F	- °F	Sy - °F	Correlation Coefficient
2	24.7	-7.8	59.1	±18.9	±1.3	0.997
8	23.3	-18.2	57.4	±17.3	±2.0	0.992
13	21.9	-21.3	56.2	±16.0	±1.5	0.956
16	23.8	-16.1	56.9	±17.7	±2.3	0.99[illegible]

$$T = a\,[\,\sin(bx + c)\,] + \overline{T}$$

where

T = water temperature in degrees Fahrenheit

a = amplitude in degrees Fahrenheit

$b = \frac{360°}{365 \text{ days}}$ = 0.987 degrees per day,

x = the number of days since October 1, (x = 1 for October 1)

c = phase coefficient in degrees, and

$\overline{T}$ = average temperature in degrees Fahrenheit

The constants a, c, and $\overline{T}$ were computed by the method of least squares. The standard deviation was computed by the equation:

$$= \frac{\Sigma(T-\overline{T})^2}{n-1}$$

The standard error of estimate was computed by the equation:

$$Sy = \frac{\Sigma(T-Tc)^2}{n-5}$$

where:

Tc = the calculated value of T, and

n = number of observations per year = 12.

The correlation coefficient was computed by the equation:

$$CC = 1 - \frac{S_y^{2}}{{}^{2}}$$

The results obtained are summarized in Table 14.

Note that the river appears to warm up sooner in the year and to have a significantly higher average and maximum temperature at Bonner Springs than at the upstream stations.

The temperature should continue to be monitored at this station to determine if these characteristics persist over a normal period of record.

The fit of the computed temperature curve to the observed data is illustrated in Figures 43 and 44. In these figures, the temperatures have been converted to degrees Centigrade and all of the observed data has been plotted. The numbers opposite some of the data points indicate the total number of duplicate observations. Each figure also has one year of data emphasized by a black dot to illustrate the fit of the average curve to a particular year.

The variation of water temperature in the reservoirs surrounding the model region can be expected to be less extreme and out-of-phase with the stream temperatures, because of the heat capacity of the large volumes of water in storage. The effect of reservoir releases on stream water temperature will probably be minimal, however, because of the normally low release rate from the reservoirs and the large surface-area-to-depth ratio of the streams, which will permit rapid equilibration between the air and water temperature. This is especially true during periods when low-flow augmentation would be desireable.

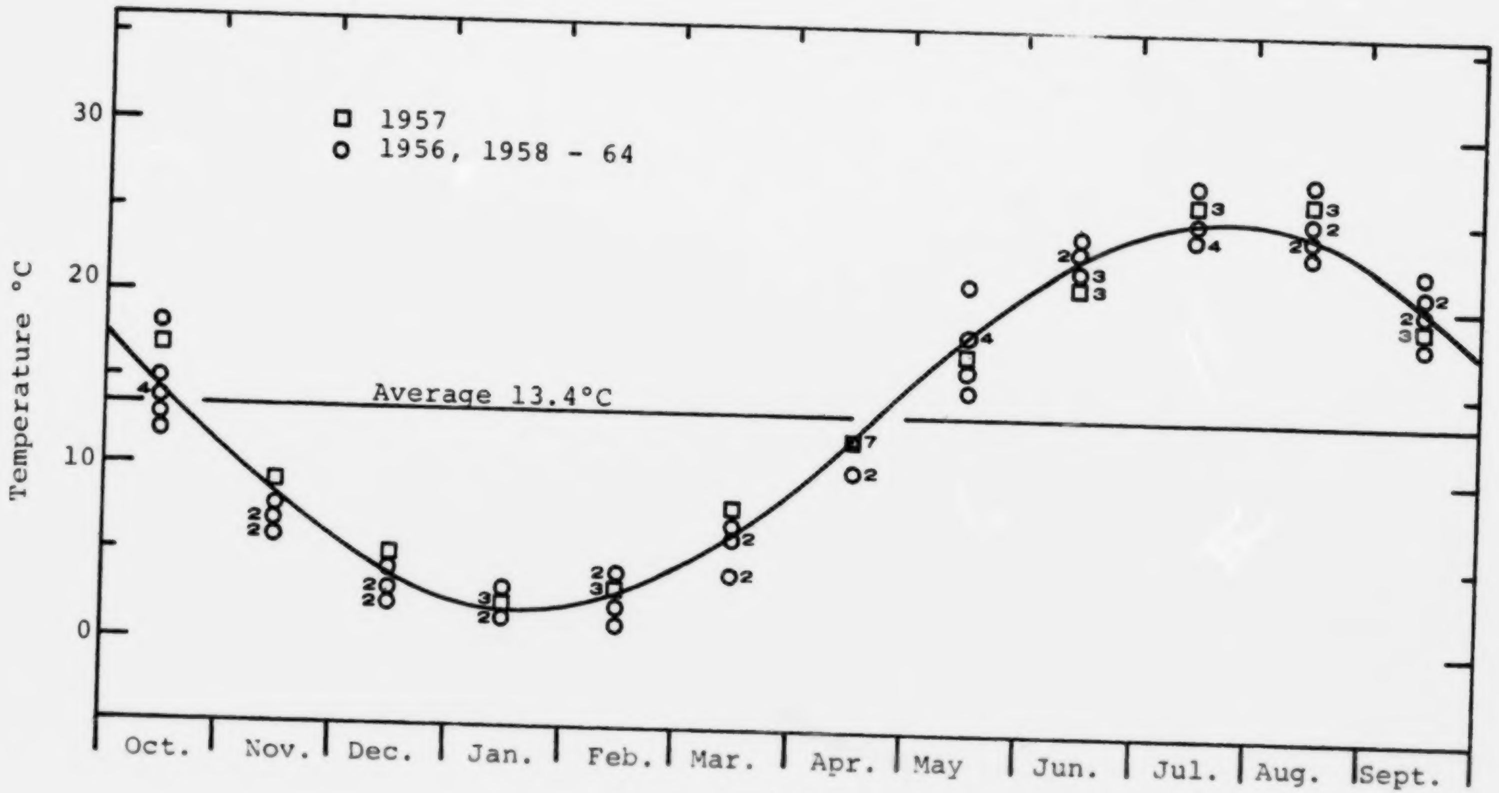


Figure 43 Computed and Observed Average Monthly Water Temperature in Degrees Centigrade for Water Quality Station Number 13; The Smoky Hill River at Enterprise. The numbers adjacent to the symbols indicate identical observations in different years.

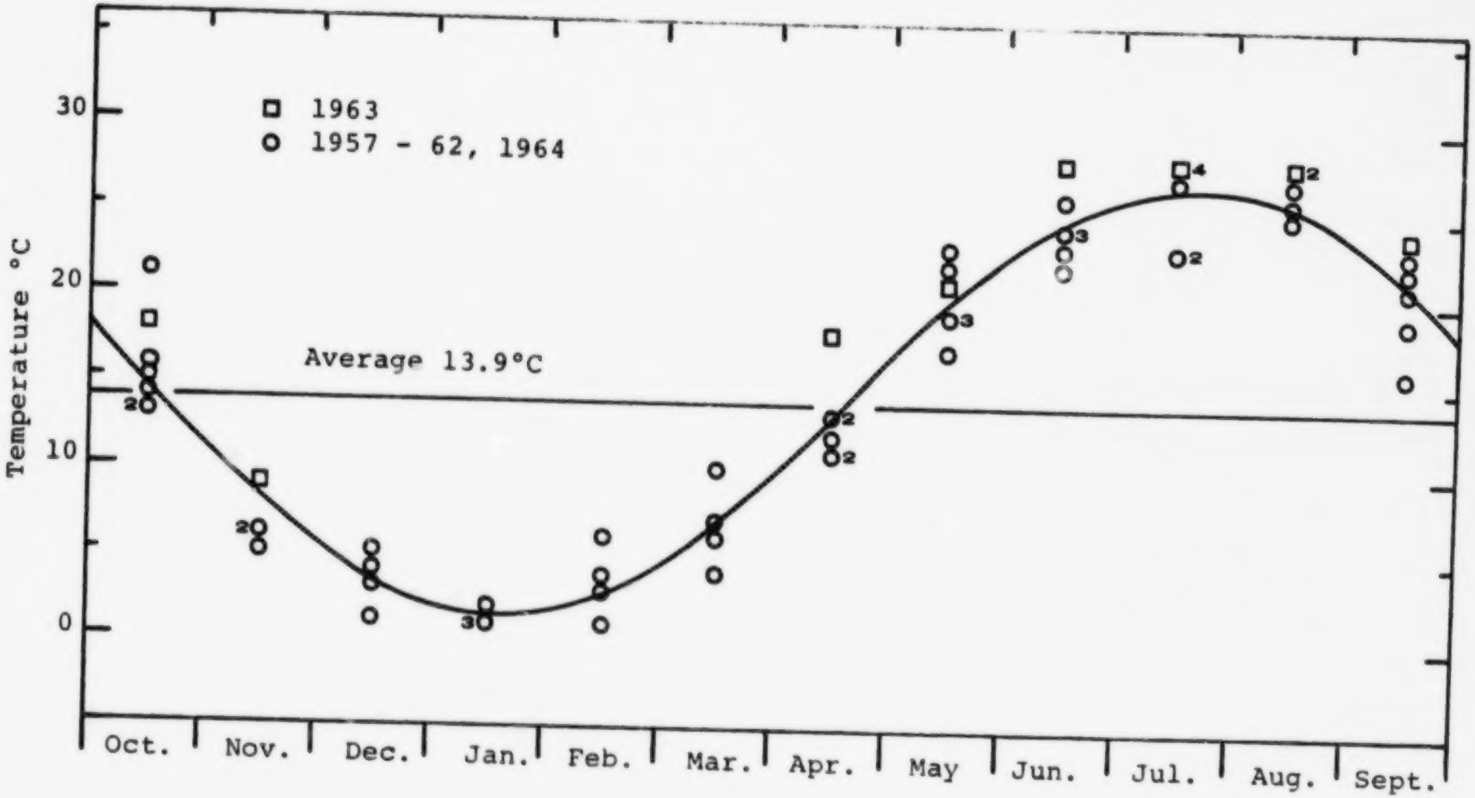


Figure 44 Computed and Observed Average Monthly Water Temperature in Degrees Centigrade for Water Quality Station Number 8; The Kansas River at Wamego. The numbers adjacent to the symbols indicate identical observations in different years.

VIII. Modification of the Fixed Vector

The fixed vector is used to physically define the river network in the computer. The techniques and assumptions used in determining the numerical values for this vector were presented in the earlier report (1). A thorough review of these values was conducted under this contract and a number of modifications have been made. These are:

1. Numerical changes have been made in the coefficients and exponents of the velocity equations for reaches 55, 58, 59, 64, 65, 176, and 220.
2. Numerical changes have been made in the coefficients and exponents of the hydraulic depth equations for reaches 55, 58, 59, 64, 65, 135, 145, 154, 155, and 165.
3. Reaches 208 and 209, located between Tescott and Sylvan Grove, Kansas on the Saline River are now each divided into two reaches. This was done because the results produced during the testing of the translation procedure indicated the time of flow within these reaches was approaching, and at times exceeding, the preassigned nine day limit established in the control section of the model.
4. Gage 29 is now used to develop QADD for reaches 206, 207, 208, 209, 210 and 175. This was done to improve the detection of the isolated summer thunderstorms which occur in this region and usually travel in a northeasterly direction.

This change has improved the magnitude and timing of most of the sharp discharge peaks observed at gages 21 and 24.

5. The lengths of all end reaches containing gages, with the exception of reach 141, were reduced to 0.0 miles. This change was made so the input hydrographs would enter the model as they occur at the recording gages. Reach 141 was not reduced in length because it presents a fine example of how to treat pollution loading from areas upstream from a gage. Reach 142 which is upstream from reach 141 was reduced to 0.0 miles, thereby representing the point source of pollution. Although the hydrographs recorded at gage 17 are translated through the 51.0 miles of reach 141, no apparent discrepancy occurs in the reconstituted hydrographs or water quality predictions downstream of reach 141. This is probably due to the small volumes of flow normally occurring in Lyons Creek. One approach which could also be used in cases similar to the above is to assume the point source of pollution is located at the gage, thus eliminating the necessity for translating both discharges and loads. This approach is considered adequate when using the model for inorganic pollution analyses. However, when analyzing organic pollution, some discrepancies can be expected because the natural decay process is not considered.

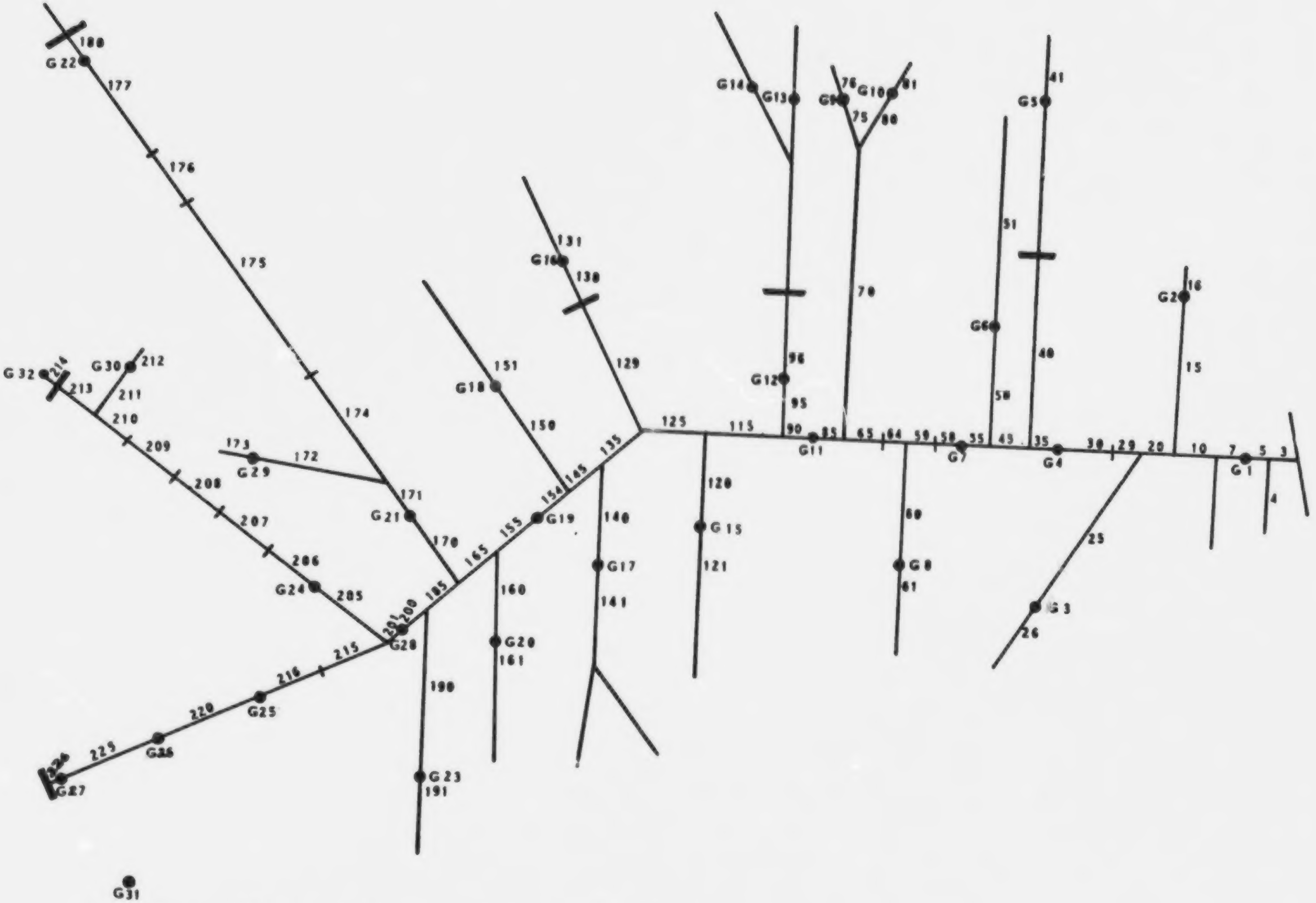
Reach 4 is an example of how to place an ungaged tributary into the system when it is apparent that significant amounts of pollution originate in its drainage basin. Although reach 4 contributes insignificant inorganic loads, it does contribute organic pollutants to the model area. This reach has an established length of 11.0 miles. The input hydrograph is derived by the techniques previously cited for generating QADD (1), and the flow is translated through the reach.

6. Reach 62 was removed from the vector because it was located upstream from gage 8 and does not contribute significant quantities of inorganic pollution to the model. It should be retained in the model when organic pollutants are being considered because of the wastewater discharge at Alma.
7. Reach 59 was reduced to 10.1 miles in length and reach 58 with a length of 9.0 miles was added to the model. This was done to account for a 10.1 mile error in river length between Topeka and Lawrence.

All of these corrections have been incorporated into the fixed vector presented in Appendix H. A graph of the reach and gage network used to define the river system in the computer is given in Figure 45.

The Federal Water Pollution Control Administration and the Kansas State Department of Health have also conducted time-of-travel measurements on the river system in the model area. The data obtained by the Kansas State Department of Health has been published (17). The measurements by both organizations indicate the logarithmic relationship between velocity or hydraulic depth and discharge proposed by Leopold and Maddock (18) is applicable for the rivers in the basin unless an overflow dam or other artificial channel control is present. Excellent agreement between the measured time of flow and the velocity relationships developed from the rating curves of the U.S.G.S. discharge gaging stations was obtained at all stations except gages 25, 26, and 27 on the Smoky Hill River. The predicted relationships for velocity as a function of discharge were low at all of these sites. The apparent reason for these discrepancies is pooling in the river channel immediately adjacent to the gages. A list of modified velocity and hydraulic depth relationships based on the time of flow measurements is given in Table 15. These modifications are not included in the fixed vector given in Appendix H.

In the reaches of the river immediately upstream from low head overflow dams or other artificial channel controls, the flow velocity is significantly retarded and the hydraulic depth increased during periods of low discharge. This occurs at reach 30 on the Kansas River immediately upstream of the Bowerstock Dam at Lawrence, in reaches 176, 177, and 180 on the Solomon River, and in reaches 213 and 214 on the Saline River. The variation in velocity and hyraulic depth for all of these reaches can be adequately defined for the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G28
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G27
G31

Figure 45: Reach and Gage Numbering System for the Lower Kansas River Model.

model by using two logarithmic equations and a critical discharge point for transfer between relationships as was done for the conservative pollutant load add relationships. A set of equations for each of the effected reaches is given in Table 16. The headings VAA, VBA, HAA, and HBA in the table refer to the coefficients and exponents of the discharge term in the logarithmic equations describing the variation in velocity and hydraulic depth for the range from one cubic foot per second to the critical discharge, QCRIT. The coefficients and exponents of the discharge term in the equations applicable for the range from the critical discharge to the largest value considered in the model are designated by VAB, VBB, HAB, and HBB. The upper limit of discharge has been arbitrarily set at one hundred thousand cubic feet per second.

Modifying the computer program to accept the equations presented in Table 16 would be of little practical significance in the conservative model because the velocity changes occur only at relatively low discharges and the effect on the conservative load will be quite small. The effect of these changes on the reaeration coefficient will be very significant however. The non-conservative model would therefore be improved if the computer program were modified to accept the new equations.

Table 15

Modifications to the Fixed Vector Based on the 1967

Time of Flow Measurements

Reach	HA	HB	VA	VB
85	0.086	0.454	0.225	0.270
90	0.086	0.454	0.225	0.270
115	0.120	0.420	0.234	0.291
125	0.120	0.420	0.234	0.291
215	0.288	0.404	1.25	0.159
216	0.288	0.404	1.25	0.159
220	0.140	0.507	1.25	0.159
225	0.330	0.330	1.103	0.213
226	0.501	0.501	1.103	0.213

Table 16

Modification of the Fixed Vector Necessary to Include the Effects of Channel Control Structures on the Velocity and Hydraulic Depth Which Occur at Low Discharges

Reach	HAA	HBA	VAA	VBA	QCRIT	HAB	HBB	VAB	VBB
30	0.312	0.305	0.007	0.646	12,000	0.013	0.640	0.268	0.210
176	2.516	0.115	0.195	0.372	950	0.160	0.152	0.795	0.167
177	2.516	0.115	0.195	0.372	950	0.160	0.152	0.795	0.167
180	2.516	0.115	0.195	0.372	950	0.160	0.152	0.795	0.167
213	1.130	0.123	0.077	0.556	270	0.153	0.481	0.557	0.199
214	1.130	0.123	0.077	0.556	270	0.153	0.481	0.557	0.199

IX. Summary and Recommendations

The status of the water quality parameters entering the Lower Kansas River Basin Model may be summarized as follows:

1. A new discharge translation procedure has been developed for the model. This modification has little impact on the numerical values of the discharges generated in the hydrologic portion of the river system but significantly improves the accuracy of the budgeting procedure used in accounting for the variation in the conservative and non-conservative load at any location in the basin.
2. Sets of conservative vectors for predicting the concentration of chloride, sulfate, calcium and magnesium have been tested and found to satisfactorily reproduce the variation in conservative load at various locations in the region. Unfortunately, a considerable amount of hand calculation is required to develop a set of these vectors. Continued research should be directed toward developing a computer program for processing the basic data into a format suitable for use in the model.
3. A method for predicting the percentage composition and the concentration of conservative pollutants in reservoirs from pre-impoundment measurements has been developed. Continued research should be

conducted toward further refining and testing this method. This will require post-impoundment water quality measurements at Perry, Milford, and Glen Elder Reservoirs.

4. The non-conservative water quality measurements obtained by the Kansas State Department of Health have been analyzed and presented in a format applicable for use in the Lower Kansas River Basin Model. Photosynthesis was found to exhibit a significant effect on stream dissolved oxygen concentration at the present time. This effect will become even more pronounced after all the reservoirs in the area are completed. Plan should be made to monitor photosynthetic activity as part of data input for the water management program used in the basin.
5. The most serious shortcoming of the non-conservative model continues to be the lack of a unique prediction method for the reaeration coefficient in alluvial streams. A program for establishing the value of this parameter should be undertaken.
6. The average monthly stream water temperature was found to follow the sine equation proposed by Ward (16). These computations should be reviewed after several additional years of data are available for the Kansas River at Bonner Springs to determine if the apparent downstream warming trend shown by the current data is valid.

7. The logarithmic relationship between velocity or hydraulic depth and discharge proposed by Leopold and Maddock (18) is applicable for the rivers in the basin unless an overflow dam or other channel control is present. In these latter cases the observed variation in velocity with discharge can be satisfactorily approximated by two discontinuous logarithmic equations.

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APPENDIX A

Modified Dynamic Conservative Model of the Lower Kansas River Basin

```
[illegible]
      CALL [illegible]
      [illegible]
      IDS=
[illegible]
      DO [illegible] I=1,26
      IF([illegible]
[illegible]
```

```
   1Q2(I)
 41 FORMAT(5X,I8,I10,I8,6X,F7.2,F11.3,2F9.3,F11.3,2I10)
 30 CONTINUE
    WRITE(6,22)
 22 FORMAT(1H1//10X,115HREACH    UPPER REACHES       LENGTH        QADC
   1    CAA        CAB         CAC        CAD         QADC2          CAF
   2CAF)
    DO 31 I=1,226
    IF(SKIP(I).LE.0) GO TO 31
    READ(5,42) QADC(I),CAA(I),CAB(I),CAC(I),CAD(I),QADC2(I),CAF(I),CAF
   1(I)
 42 FORMAT(4F10.0,F7.0,3F8.0)
    WRITE(6,43) I,UR1(I),UR2(I),L(I),QADC(I),CAA(I),CAB(I),CAC(I),CAD(
   1I),QADC2(I),CAF(I),CAF(I)
 43 FORMAT(5X,I10,2I8,F8.2,F10.0,4F10.3,F10.0,2F10.3)
 31 CONTINUE
    DO 2010 I=1,226
    IF(SKIP(I).LE.0) GO TO 2010
    IF(QADC2(I).LE.0.0)QADC2(I)=100000.
2010 CONTINUE
    NNN=1
    DO 101 JJJ=1,226
    I=227-JJJ
    IF(SKIP(I).LE.0) GO TO 101
    IF(I.NE.NPT(NNN)) GO TO 101
    READ(5,61) NUM(NNN)
 61 FORMAT(I10)
    WRITE(6,603)
603 FORMAT(1H0,20X,25HQCRIT          A          B)
    LNUM=NUM(NNN)
    DO 601 J=1,LNUM
    READ(5,602)QCRIT(NNN,J),A(NNN,J),B(NNN,J)
602 FORMAT(F10.0,F20.0,F10.0)
    WRITE(6,605)I,QCRIT(NNN,J),A(NNN,J),B(NNN,J)
605 FORMAT(1H ,5X,I10,F10.0,2F14.3)
601 CONTINUE
```

```
      NNN=NNN+1
      IF(NNN.EQ.7) NNN=1
  100 CONTINUE
CALCULATION OF FLOWS IN THE REACHES
C   INPUT OF GAGE FLOW
   10 READ(5,27)ND,IDATE1,IDATE2
   27 FORMAT(I10,2A6)
      IF(ND.LE.0)GO TO 99
      DO 35 I=1,226
      DO 25 J=1,ND
      COUT(I,J)=0.0
   25 QOUT(I,J)=0.0
   35 CONTINUE
      DO 29 J=1,32
      READ(5,28) (GAGE(J,N),N=1,ND)
   28 FORMAT(9F8.0)
   29 CONTINUE
      DO 37 J=1,ND
   37 GAGE(1,J)=0.0
      MCK=IP
      NNN=1
      DO 60 LK=1,226
      I=227-LK
      IF(SKIP(I).LE.0) GO TO 60
      JR1= IR1(I)
      JR2=IR2(I)
      JG1=IG1(I)
      JG2=IG2(I)
      NT=1.0
      GO TO 51
   52 ITME=ITME+1
      IF(ITME.GT.ND)GO TO 55
      GO TO 50
   51 ITME=NT
   50 QADD=QAA(I)*(GAGE(JG1,ITME)+GAGE(JG2,ITME))+QAB(I)
      QRCH(ITME)=QADD+QOUT(JR1,ITME)+QOUT(JR2,ITME)
      IF(QRCH(ITYPE).LT.1.0)QRCH(ITYPE)=1.0
      IF(I.NE.NPT(NNN)) GO TO 600
      LNUMB = NUB(NNN)
      DO 605 K=1.LNUMB
      CADD=A(NNN.K)*QRCH(ITYPE)**B(NNN.K)
      IF(QCRIT(NNN.K).GT.QRCH(ITYPE))GO TO 2001
  605 CONTINUE
  600 IF(QADD.GE.QADC(I))GO TO 2000
      CADD=CAA(I)*(QADD**CAB(I))
      GO TO 2001
 2000 IF(QADD.GE.QADC2(I)) GO TO 2002
      CADD=CAC(I)*(QADD**CAD(I))
      GO TO 2001
 2002 CADD=CAE(I)*(QADD**CAF(I))
 2001 CRCH(ITYPE)=CADD+COUT(JR1.ITYPE)+COUT(JR2.ITYPE)
      V=VA(I)*QRCH(ITYPE)**VB(I)
      TF=L(I)/(16.4*V)
      IF(TF.LT.1.0)GO TO 1000
      IF(ITYPE.NE.1)GO TO 2
      QOUT(I.1)=QRCH(1)
      COUT(I.1)=CRCH(1)
    2 IF(TF.EQ.1.0)GO TO 1001
      IF(TF.GT.1.0 .AND.TF.LT.2.0)GO TO 1002
      IF(ITYPE.NE.1)GO TO 3
      QOUT(I.2)=QRCH(1)
      COUT(I.2)=CRCH(1)
    3 IF(TF.EQ.2.0)GO TO 1003
      IF(TF.GT.2. .AND.TF.LT.3.0)GO TO 1004
      IF(ITYPE.NE.1)GO TO 4
      QOUT(I.3)=QRCH(1)
      COUT(I.3)=CRCH(1)
    4 IF(TF.EQ.3. )GO TO 1005
      IF(TF.GT.3. .AND.TF.LT.4.0)GO TO 1006
      IF(ITYPE.NE.1)GO TO 5
      QOUT(I.4)=QRCH(1)
      COUT(I.4)=CRCH(1)
```

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    5 IF(TF.EQ.4.0)GO TO 1007
      IF(TF.GT.4.0.AND.TF.LT.5.0)GO TO 1008
      IF(ITME.NE.1)GO TO 6
      QOUT(I.5)=QRCH(1)
      COUT(I.5)=CRCH(1)
    6 IF(TF.EQ.5.0)GO TO 1009
      IF(TF.GT.5.0.AND.TF.LT.6.0)GO TO 1010
      IF(ITME.NE.1)GO TO 7
      QOUT(I.6)=QRCH(1)
      COUT(I.6)=CRCH(1)
    7 IF(TF.EQ.6.0)GO TO 1011
      IF(TF.GT.6.0.AND.TF.LT.7.0)GO TO 1012
      IF(ITME.NE.1)GO TO 8
      QOUT(I.7)=QRCH(1)
      COUT(I.7)=CRCH(1)
    8 IF(TF.EQ.7.0)GO TO 1013
      IF(TF.GT.7.0.AND.TF.LT.8.0)GO TO 1014
      IF(ITME.NE.1)GO TO 9
      QOUT(I.8)=QRCH(1)
      COUT(I.8)=CRCH(1)
    9 IF(TF.EQ.8.0)GO TO 1015
      IF(TF.GT.8.0.AND.TF.LT.9.0)GO TO 1016
      IF(TF.GE.9.0)GO TO 1017
 1000 QOUT(I.ITME)=QOUT(I.ITME)+QRCH(ITME)*(1.0-TF)
      COUT(I.ITME)=COUT(I.ITME)+CRCH(ITME)*(1.0-TF)
      INMAN=ITME+1
      IF(INMAN.GT.ND)GO TO 52
      QOUT(I.INMAN)=QOUT(I,INMAN)+QRCH(ITME)*TF
      COUT(I,INMAN)=COUT(I.INMAN)+CRCH(ITME)*TF
      GO TO 52
 1001 ITME1=ITME+1
      IF(ITME1.GT.ND)GO TO 52
      QOUT(I.ITME1)=QOUT(I,ITME1)+QRCH(ITME)
      COUT(I.ITME1)=COUT(I,ITME1)+CRCH(ITME)
      GO TO 52
 1002 ITME2=ITME+1
```

```
      IF(ITME2.GT.ND)GO TO 52
      F1=2.0-TF
      QOUT(I.ITME2)=QOUT(I.ITME2)+QRCH(ITME)*F1
      COUT(I.ITME2)=COUT(I.ITME2)+CRCH(ITME)*F1
      ITME3=ITME2+1
      IF(ITME3.GT.ND)GO TO 52
      F2=1.0-F1
      QOUT(I.ITME3)=QOUT(I.ITME3)+QRCH(ITME)*F2
      COUT(I.ITME3)=COUT(I.ITME3)+CRCH(ITME)*F2
      GO TO 52
 1003 ITME4=ITME+2
      IF(ITME4.GT.ND)GO TO 52
      QOUT(I.ITME4)=QOUT(I.ITME4)+QRCH(ITME)
      COUT(I.ITME4)=COUT(I.ITME4)+CRCH(ITME)
      GO TO 52
 1004 ITME5=ITME+2
      IF(ITME5.GT.ND)GO TO 52
      F3=3.0-TF
      QOUT(I.ITME5)=QOUT(I.ITME5)+QRCH(ITME)*F3
      COUT(I.ITME5)=COUT(I.ITME5)+CRCH(ITME)*F3
      ITME6=ITME5+1
      IF(ITME6.GT.ND)GO TO 52
      F4=1.0-F3
      QOUT(I.ITME6)=QOUT(I.ITME6)+QRCH(ITME)*F4
      COUT(I.ITME6)=COUT(I.ITME6)+CRCH(ITME)*F4
      GO TO 52
 1005 ITME7=ITME+3
      IF(ITME7.GT.ND)GO TO 52
      QOUT(I.ITME7)=QOUT(I.ITME7)+QRCH(ITME)
      COUT(I.ITME7)=COUT(I,ITME7)+CRCH(ITME)
      GO TO 52
 1006 ITME8=ITME+3
      IF(ITME8.GT.ND)GO TO 52
      F5=4.0-TF
      QOUT(I.ITME8)=QOUT(I.ITME8)+QRCH(ITME)*F5
      COUT(I.ITME8)=COUT(I.ITME8)+CRCH(ITME)*F5
      ITME9=ITME8+1
      IF(ITME9.GT.NN)GO TO 52
      F6=1.0-F5
      QOUT(I.ITME9)=QOUT(I.ITME8)+QRCH(ITME1)*F6
      COUT(I.ITME9)=COUT(I.ITME8)+CRCH(ITME1)*F6
      GO TO 52
 1007 ITME10=ITME+4
      IF(ITME10.GT.NN)GO TO 52
      QOUT(I.ITME10)=QOUT(I.ITME10)+QRCH(ITME1)
      COUT(I.ITME10)=COUT(I.ITME10)+CRCH(ITME1)
      GO TO 52
 1008 ITME11=ITME+4
      IF(ITME11.GT.NN)GO TO 52
      F7=5.0-TF
      QOUT(I.ITME11)=QOUT(I.ITME11)+QRCH(ITME1)*F7
      COUT(I.ITME11)=COUT(I.ITME11)+CRCH(ITME1)*F7
      ITME12=ITME11+1
      IF(ITME12.GT.NN)GO TO 52
      F8=1.0-F7
      QOUT(I.ITME12)=QOUT(I.ITME12)+QRCH(ITME1)*F8
      COUT(I.ITME12)=COUT(I.ITME12)+CRCH(ITME1)*F8
      GO TO 52
 1009 ITME13=ITME+5
      IF(ITME13.GT.NN)GO TO 52
      QOUT(I.ITME13)=QOUT(I.ITME13)+QRCH(ITME1)
      COUT(I.ITME13)=COUT(I.ITME13)+CRCH(ITME1)
      GO TO 52
 1010 ITME14=ITME+5
      IF(ITME14.GT.NN)GO TO 52
      F9=6.0-TF
      QOUT(I.ITME14)=QOUT(I.ITME14)+QRCH(ITME1)*F9
      COUT(I.ITME14)=COUT(I.ITME14)+CRCH(ITME1)*F9
      ITME15=ITME14+1
      IF(ITME15.GT.NN)GO TO 52
      F10=1.0-F9
      QOUT(I.ITME15)=QOUT(I.ITME15)+QRCH(ITME1)*F10
      COUT(I.ITME15)=COUT(I.ITME15)+CRCH(ITME)*F10
      GO TO 52
 1011 ITME16=ITME+6
      IF(ITME16.GT.ND)GO TO 52
      QOUT(I.ITME16)=QOUT(I.ITME16)+QRCH(ITME)
      COUT(I.ITME16)=COUT(I.ITME16)+CRCH(ITME)
      GO TO 52
 1012 ITME17=ITME+6
      IF(ITME17.GT.ND)GO TO 52
      F11=7. -TF
      QOUT(I.ITME17)=QOUT(I.ITME17)+QRCH(ITME)*F11
      COUT(I.ITME17)=COUT(I.ITME17)+CRCH(ITME)*F11
      ITME18=ITME17+1
      IF(ITME18.GT.ND)GO TO 52
      F12=1.-F11
      QOUT(I.ITME18)=QOUT(I.ITME18)+QRCH(ITME)*F12
      COUT(I.ITME18)=COUT(I.ITME18)+CRCH(ITME)*F12
      GO TO 52
 1013 ITME19=ITME+7
      IF(ITME19.GT.ND)GO TO 52
      QOUT(I.ITME19)=QOUT(I.ITME19)+QRCH(ITME)
      COUT(I.ITME19)=COUT(I.ITME19)+CRCH(ITME)
      GO TO 52
 1014 ITME20=ITME+7
      IF(ITME20.GT.ND)GO TO 52
      F13=8. -TF
      QOUT(I.ITME20)=QOUT(I.ITME20)+QRCH(ITME)*F13
      COUT(I.ITME20)=COUT(I.ITME20)+CRCH(ITME)*F13
      ITME21=ITME20+1
      IF(ITME21.GT.ND)GO TO 52
      F14=1.-F13
      QOUT(I.ITME21)=QOUT(I.ITME21)+QRCH(ITME)*F14
      COUT(I.ITME21)=COUT(I.ITME21)+CRCH(ITME)*F14
      GO TO 52
 1015 ITME22=ITME+8
      IF(ITME22.GT.ND)GO TO 52
      QOUT(I,ITME22)=QOUT(I,ITME22)+QRCH(ITME)
      COUT(I,ITME22)=COUT(I,ITME22)+CRCH(ITME)
      GO TO 52
 1016 ITME23=ITME+8
      IF(ITME23.GT.ND)GO TO 52
      F15=9.0-TF
      QOUT(I,ITME23)=QOUT(I,ITME23)+QRCH(ITME)*F15
      COUT(I,ITME23)=COUT(I,ITME23)+CRCH(ITME)*F15
      ITME24=ITME23+1
      IF(ITME24.GT.ND)GO TO 52
      F16=1.0-F15
      QOUT(I,ITME24)=QOUT(I,ITME24)+QRCH(ITME)*F16
      COUT(I,ITME24)=COUT(I,ITME24)+CRCH(ITME)*F16
      GO TO 52
 1017 WRITE(6,1018)I,TF
 1018 FORMAT(24HPLEASE SUBDIVIDE REACH  ,I3,53H  SO THAT THE TIME OF FLO
     1W BECOMES LESS THAN 9. THANK YOU. THE TIME OF FLOW (TF) =,F6.4)
      GO TO 10
   55 IF(I.GT.IPLT1(MCK)) GO TO 59
      IF(I.LT.7) GO TO 60
      LMN=MCK
      WRITE(6,500)(NAMER(IQ,LMN),IQ=1,4),IDATE1,IDATE2
  500 FORMAT(1H1,19X,4A5,10X,2A6)
      WRITE(6,501)
  501 FORMAT(1H0,24X,3HDAY,10X,1HQ,10X,5HCONC,/)
      DO 502 K=1,ND
      CONC=COUT(I,K)/((0.0027)*QOUT(I,K))
      WRITE(6,503) K,QOUT(I,K),CONC
  503 FORMAT(1H ,23X,I4,4X,F10.0,4X,F10.4)
  502 CONTINUE
      MCK=MCK-1
      IF(MCK.LT.1) MCK=1
   59 IF(I.NE.NPT(NNN)) GO TO 60
      NNN=NNN+1
      IF(NNN.EQ.7) NNN=6
   60 CONTINUE
```

```
      GO TO 10
   99 CALL CLOCK (-1)
      STOP
      END
```

APPENDIX B

Summary of Program Symbols for the Modified Dynamic Conservative Model of the Lower Kansas River Basin

Summary of Program Symbols for the Modified Dynamic Conservative Model of the Lower Kansas River Basin

A - Coefficient for CADD function from reservoirs.

B - Exponent for CADD function from reservoirs.

CAA - Coefficient for CADD function.

CAB - Exponent for CADD function.

CAC - Coefficient for CADD function.

CAD - Exponent for CADD function

CADD - Tons per day of a conservative pollutant added locally.

CAE - Coefficient for CADD function.

CAF - Exponent for CADD function.

CONC - Concentration in mg/l of a conservative pollutant.

COUT - Tons per day of a conservative pollutant leaving a reach.

CRCH - Tons per day of a conservative pollutant entering a reach.

GAGE - Boundary condition stream-gage reading in c.f.s.

H - Hydraulic depth in reach in feet.

HA - Coefficient for H function.

HB - Exponent for H function.

I - Integer identifier for reach.

IDATE1 - Identifier for date of historic period.

IDATE2 - Identifier for date of historic period.

IG1 - Integer identifier of stream gage for QADD function.

IG2 - Integer identifier of stream gage for QADD function.

ITME - Day of the period.

JG1 - Non-subscripted form of IG1.

JG2 - Non-subscripted form of IG2.

JR1 - Non-subscripted form of UR1.

JR2 - Non-subscripted form of UR2.

L - Length of reach in miles.

LK - Dummy interation integer.

MCK - Dummy variable.

N - Iteration integer.

ND - Number of days in period.

NNN - Identifier of a reservoir reach.

NPT - Identifier of routine for reservoir identification.

NUM - Equation identifier for CADD function for reservoirs.

QAA - Coefficient of QADD function.

QAB - Constant of QADD function.

QADC - First breakpoint on CADD furction.

QADC2 - Second breakpoint on CADD function.

QADD - Discharge directly into reach from surface runoff and groundwater.

QCRIT - Breakpoint on CADD function for reservoirs.

QOUT - Discharge out of a reach in c.f.s.

QRCH - Discharge in a reach in c.f.s.

S - Mean bed slope of the reach.

SKIP - Indicator of the existence or non-existence of a reach.

UR1 - Identity of an upstream reach.

UR2 - Identity of a second upstream reach (tributary).

V - Average velocity of flow in ft/sec.

VA - Coefficient of V function.

VB - Exponent of V function.

APPENDIX C

Chloride Conservative Vector

[illegible]	[illegible]	[illegible]	[illegible]	CAC	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
141	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.67	57.2	0.	[illegible]	0.0	1.
[illegible]	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
154	150.	2.	0.670	57.2	0.	[illegible]	0.0	1.
[illegible]	240.	4.53	0.8167	6776.	-0.516			
[illegible]	240.	4.53	0.8167	6776.	-0.516			
161	240.	4.53	0.8167	6776.	-0.516			
[illegible]	240.	4.53	0.8167	6776.	-0.516			
170	240.	4.53	0.8167	6776.	-0.516			
171	275.	0.919	0.842	7316.	-0.753	15.0.	0.0	1.
172	275.	0.919	0.842	7316.	-0.753	15.0.	0.0	1.
173	275.	0.919	0.842	7316.	-0.753	15.0.	0.0	1.
174	275.	0.919	0.842	7316.	-0.753	15.0.	0.0	1.
175	275.	0.919	0.842	7316.	-0.753	15.0.	0.0	1.
176	275.	0.919	0.842	7316.	-0.753	15.0.	0.0	1.

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```
REACH  QADC       CAA        CAB         CAC          CAD  QADC2     CAE      CAF

  177  275.      0.219      0.642       7316.       -0.753  150.     0.0      1.0
  18   275.      0.219      0.642       7316.       -0.753  150.     0.0      1.0
  185  240.      4.53       0.8167      6776.       -0.516
  19   240.      4.53       0.8167      6776.       -0.516
  191  240.      4.53       0.8167      6776.       -0.516
  20   240.      4.53       0.8167      6776.       -0.516
  201  240.      4.53       0.8167      6776.       -0.516
  205  240.      4.53        .8167      6776.       -0.516
  206  585.      0.977      0.966       8113.       -0.453
  207  585.      0.977      0.966       8113.       -0.453
  208  585.      0.977      0.966       8113.       -0.453
  209  585.      0.977      0.966       8113.       -0.453
  21   585.      0.977      0.966       8113.       -0.453
  211  585.      0.977      0.966       8113.       -0.453
  212  585.      0.977      0.966       8113.       -0.453
  213  585.      0.977      0.966       8113.       -0.453
  214  585.      0.977      0.966       8113.       -0.453
  215  240.      4.53       0.8167      6776.       -0.516
  216  240.      4.53       0.8167      6776.       -0.516
  22   240.      4.53       0.8167      6776.       -0.516
  225  240.      4.53       0.8167      6776.       -0.516
  226  240.      4.53       0.8167      6776.       -0.516
```

APPENDIX D

Sulfate Conservative Vector

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APPENDIX D

Sulfate Conservative Vector

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[illegible]	[illegible]	CAA	CAB	CAC	CAD	CAFC2	CAE	CAF
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-1.07	[illegible]	[illegible]	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	27.1	.364	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	27.1	.364	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	27.1	.364	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	27.1	.364	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	27.1	.364	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	1.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.335	[illegible]	0.0	1.0

```
REACH  QADC       CAA       CAB        CAC         CAD    QADC2      CAE      CAF

 177   73.       0.337      .759       39.4      -0.33[illegible]  200.      0.0      1.0
 180   73.       0.337     0.759       39.4      -0.33[illegible]  200.      0.0      1.0
 185   250.      1.41      0.970       27.01      0.364  500.       0.0      1.0
 190   250.      1.41      0.970       27.01      0.364  500.       0.0      1.0
 191   250.      1.41      0.970       27.01      0.364  500.       0.0      1.0
 200   250.      1.41      0.970       27.01      0.364  500.       0.0      1.0
 201   250.      1.41      0.970       27.01      0.364  500.       0.0      1.0
 205   250.      1.41      0.970       27.01      0.364  500.       0.0      1.0
 206   810.      0.180     1.175       50512.    -0.[illegible]  4000.     0.0      1.0
 207   810.      0.180     1.175       50512.    -0.[illegible]  4000.     0.0      1.0
 208   810.      0.180     1.175       50512.    -0.[illegible]  4000.     0.0      1.0
 209   810.      0.180     1.175       50512.    -0.[illegible]  4000.     0.0      1.0
 210   810.      0.180     1.175       50512.    -0.[illegible]  4000.     0.0      1.0
 211   810.      0.180     1.175       50512.    -0.[illegible]  4000.     0.0      1.0
 212   810.      0.180     1.175       50512.    -0.[illegible]  4000.     0.0      1.0
 213   810.      0.180     1.175       50512.    -0.[illegible]  4000.     0.0      1.0
 214   810.      0.180     1.175       50512.    -0.[illegible]  4000.     0.0      1.0
 215   250.      1.41      0.970       27.01      0.364  500.       0.0      1.0
 216   250.      1.41      0.970       27.01      0.364  500.       0.0      1.0
 220   250.      1.41      0.970       27.01      0.364  500.       0.0      1.0
 225   250.      1.41      0.970       27.01      0.364  500.       0.0      1.0
 226   250.      1.41      0.970       27.01      0.364  500.       0.0      1.0
```

```
REACH   QCRIT      A           B

 226    10000.     0.55        0.911

 214    10000.     4.86        0.554

 180    400.       0.683       0.951
 180    1600.      4.51        0.638
 180    8000.      202797.    -0.810
 180    10000.     0.0         1.0

 131    1020.      0.344       0.910
 131    2440.      8.29        0.454
 131    8000.      280.        0.0
 131    10000.     0.0         1.0

  96    2500.      0.186       0.941
  96    10000.     1.74        0.655

  41    3000.      0.438       0.756
```

APPENDIX E

Calcium Conservative Vector

```
                                  CALCIUM

REACH  QADC       CAA       CAB        CAC        CAD  QADC2    CAE    CAF
    3  10000.    0.117     1.051
    4  10000.    0.117     1.051
    5  10000.    0.117     1.051
    7  10000.    0.117     1.051
   10  10000.    0.117     1.051
   15  10000.    0.117     1.051
   16  10000.    0.117     1.051
   20  10000.    0.117     1.051
   25  10000.    0.117     1.051
   26  10000.    0.117     1.051
   29  10000.    0.117     1.051
   30  10000.    0.117     1.051
   35  10000.    0.186     0.978
   40  10000.    0.186     0.978
   41  10000.    0.186     0.978
   45  10000.    0.186     0.978
   50  10000.    0.186     0.978
   51  10000.    0.186     0.978
   55  10000.    0.186     0.978
   58  10000.    0.186     0.978
   59  10000.    0.186     0.978
   60  10000.    0.186     0.978
   61  10000.    0.186     0.978
   64  10000.    0.186     0.978
   65  10000.    0.186     0.978
   70  10000.    0.186     0.978
   75  10000.    0.186     0.978
   76  10000.    0.186     0.978
   80  10000.    0.186     0.978
   81  10000.    0.186     0.978
```

```
REACH  QADC       CAA       CAB       CAC       CAE    QADC2      CAG       CAF

  85   1[illegible].   [illegible].186   [illegible].974
  9[illegible]   760.      0.606     0.841     4.423
  96   760.      0.606     0.841     4.423     .040   2150.    124215.   -0.792
  96   760.      0.606     0.841     4.423    0.040   2150.    124215.   -0.792
 115   760.      0.606     0.841     4.423     .040   215[illegible].    124215.   -0.74[illegible]
 12[illegible]   76[illegible].      0.6[illegible]     .841     4.423     .04[illegible]   215[illegible].    124[illegible]15.   -0.74[illegible]
 121   76[illegible].      0.6[illegible]     .841     4.4[illegible]     .[illegible]   [illegible].    [illegible].   -[illegible].[illegible]
 125   76[illegible].      0.6[illegible]     .841     4.42[illegible]     .[illegible]   [illegible].    [illegible].   -[illegible].[illegible]
 129   76[illegible].      0.6[illegible]     0.841     4.423     .[illegible]   21[illegible].    [illegible].   -[illegible].[illegible]
 13[illegible]   76[illegible].      0.6[illegible]     .841     4.42[illegible]     .[illegible]   [illegible].    [illegible].   -[illegible].[illegible]
 131   76[illegible].      0.6[illegible]     .841     4.4[illegible]     .[illegible]   [illegible].    [illegible].   -[illegible].[illegible]
 1[illegible]   7[illegible].      .5[illegible]     .841     4.423     .[illegible]   [illegible].    [illegible].   -[illegible].[illegible]
 14[illegible]   76[illegible].      .6[illegible]     .84[illegible]     4.4[illegible]     .[illegible]   [illegible].    [illegible].   -[illegible].[illegible]
 141   76[illegible].      .6[illegible]     .84[illegible]     4.42[illegible]     .[illegible]   [illegible].    [illegible].   -[illegible].[illegible]
 14[illegible]   76[illegible].      .6[illegible]     .84[illegible]     4.42[illegible]     .[illegible]   [illegible].    [illegible].   -[illegible].[illegible]
 14[illegible]   76[illegible].      .6[illegible]     .84[illegible]     4.4[illegible]     .[illegible]   [illegible].    [illegible].   -[illegible].[illegible]
 15[illegible]   76[illegible].      .6[illegible]     .84[illegible]     4.4[illegible]     .[illegible]   215.    [illegible].   -[illegible].[illegible]
 151   76[illegible].      0.6[illegible]     .84[illegible]     4.42[illegible]     .[illegible]   [illegible].    [illegible].   -[illegible].[illegible]
 1[illegible]   7[illegible].      .6[illegible]     .84[illegible]     4.42[illegible]     .[illegible]   [illegible].    [illegible].   -[illegible].[illegible]
 1[illegible]   [illegible].      .[illegible]     .84[illegible]     4.4[illegible]     .[illegible]   [illegible].    [illegible].   -[illegible].[illegible]
 16[illegible]   [illegible].      .[illegible]     .[illegible]     [illegible].    -[illegible].[illegible]   [illegible].    .[illegible]   [illegible].[illegible]
 1[illegible]   [illegible].      .[illegible]35     .[illegible]     [illegible].    -[illegible].[illegible]   [illegible].    .[illegible]   [illegible].[illegible]
 1[illegible]   [illegible].      .[illegible]     .[illegible]     [illegible].    -[illegible].[illegible]   [illegible].    .[illegible]   [illegible].[illegible]
 17[illegible]   [illegible].      .[illegible]     .[illegible]     [illegible].    -[illegible].[illegible]   6.    .[illegible]   [illegible].[illegible]
 171   [illegible].      .37[illegible]     .[illegible]     [illegible].    -[illegible].[illegible]   [illegible].    .[illegible]   [illegible].[illegible]
 17[illegible]   [illegible].      .[illegible]     .[illegible]     [illegible]00.    -[illegible].[illegible]
 17[illegible]   [illegible].      .37[illegible]     .[illegible]     [illegible]0.    -[illegible].[illegible]
 174   [illegible].      .37[illegible]     .[illegible]     [illegible]00.    -[illegible].[illegible]
 175   [illegible].      .37[illegible]     .[illegible]     [illegible]00.    -[illegible].[illegible]
 176   [illegible].      [illegible].37[illegible]     .[illegible]     [illegible]00.    -[illegible].[illegible]
```

```
REACH  QADC        CAA       CAB       CAC        CAD   QADC2     CAE     CAF

  177  265.       0.370     0.710     4266.     -1.05
  180  265.       0.370     0.710     4266.     -1.05
  185  280.       0.585     0.891     5107.     -0.724  600.     0.0     1.0
  190  280.       0.585     0.891     5107.     -0.724  600.     0.0     1.0
  191  280.       0.585     0.891     5107.     -0.724  600.     0.0     1.0
  200  280.       0.585     0.891     5107.     -0.724  600.     0.0     1.0
  201  280.       0.585     0.891     5107.     -0.724  600.     0.0     1.0
  205  280.       0.585     0.891     5107.     -0.724  600.     0.0     1.0
  206  790.       0.167     1.076     36.99     0.274
  207  790.       0.167     1.076     36.99     0.274
  208  790.       0.167     1.076     36.99     0.274
  209  790.       0.167     1.076     36.99     0.274
  210  790.       0.167     1.076     36.99     0.274
  211  790.       0.167     1.076     36.99     0.274
  212  790.       0.167     1.076     36.99     0.274
  213  790.       0.167     1.076     36.99     0.274
  214  790.       0.167     1.076     36.99     0.274
  215  280.       0.585     0.891     5107.     -0.724  600.     0.0     1.0
  216  280.       0.585     0.891     5107.     -0.724  600.     0.0     1.0
  220  280.       0.585     0.891     5107.     -0.724  600.     0.0     1.0
  225  280.       0.585     0.891     5107.     -0.724  600.     0.0     1.0
  226  280.       0.585     0.891     5107.     -0.724  600.     0.0     1.0
```

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```
REACH     QCRIT       A                    B

  226    10000.     0.340                0.941

  214    10000.     0.739                0.825

  180    1470.      0.374                0.961
  180    10000.     55.38                0.276

  131    800.       0.205                0.989
  131    3700.      1.872                0.659
  131    10000.     420.                 0.0

   96    2950.      0.194                0.972
   96    20000.     1.714                0.699

   41    10000.     0.267                0.949
```

APPENDIX F

Magnesium Conservative Vector

MAGNESIUM

```
REACH  QADC      CAA       CAB         CAC          CAD  QADC2    CAE    CAF

   3   10000.    0.021     0.977
   4   10000.    0.021     0.977
   5   10000.    0.021     0.977
   7   10000.    0.021     0.977
  10   10000.    0.021     0.977
  15   10000.    0.021     0.977
  16   10000.    0.021     0.977
  20   10000.    0.021     0.977
  25   10000.    0.021     0.977
  26   10000.    0.021     0.977
  29   10000.    0.021     0.977
  30   10000.    0.021     0.977
  35   10000.    0.0116    1.206
  40   10000.    0.0116    1.206
  41   10000.    0.0116    1.206
  45   10000.    0.0116    1.206
  50   10000.    0.0116    1.206
  51   10000.    0.0116    1.206
  55   10000.    0.0116    1.206
  58   10000.    0.0116    1.206
  59   10000.    0.0116    1.206
  60   10000.    0.0116    1.206
  61   10000.    0.0116    1.206
  64   10000.    0.0116    1.206
  65   10000.    0.0116    1.206
  70   10000.    0.0116    1.206
  75   10000.    0.0116    1.206
  76   10000.    0.0116    1.206
  80   10000.    0.0116    1.206
  81   10000.    0.0116    1.206
```

[illegible]	[illegible]	CAA	CAB	CAC	CAD	WADC2	CAE	CAF
[illegible]	1.	.116	1.2[illegible]6					
[illegible]	[illegible]	.147	.8[illegible]	59.8	-.[illegible]74	40[illegible].	.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-0.074	40[illegible].	.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-0.074	4[illegible].	0.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-.[illegible]74	40[illegible].	0.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-.[illegible]74	4000.	0.0	1.0
[illegible]	[illegible]	.147	.8[illegible]	59.8	-.[illegible]74	4[illegible].	.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-.[illegible]74	4[illegible].	0.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-0.074	4[illegible].	.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-.[illegible]74	4[illegible].	0.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-0.074	4[illegible].	0.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-0.074	4[illegible].	.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-.[illegible]74	4[illegible].	0.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-0.074	400[illegible].	.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-.[illegible]74	4000.	0.0	1.0
[illegible]	[illegible]	.147	.8[illegible]	59.8	-.[illegible]74	40[illegible].	0.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-0.074	40[illegible].	0.0	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-.[illegible]74	4[illegible].	0.	1.0
[illegible]	[illegible]	.147	0.8[illegible]	59.8	-0.074	4[illegible].	0.0	1.0
[illegible]	[illegible]	.18[illegible]	.856	1529.	-0.644			
[illegible]	[illegible]	.184	.856	1529.	-.644			
[illegible]	[illegible]	.184	.856	1529.	-.644			
[illegible]	[illegible]	.18[illegible]	0.856	1529.	-0.644			
[illegible]	[illegible]	.18[illegible]	0.856	1529.	-0.644			
[illegible]	[illegible]	.116	0.730	25.55	-0.372	40.	.0	1.0
[illegible]	[illegible]	.116	0.730	25.55	-0.372	40.	0.0	1.0
[illegible]	[illegible]	.116	.730	25.55	-.372	40.	0.0	1.0
[illegible]	[illegible]	.116	0.730	25.55	-0.372	40.	0.0	1.0
[illegible]	[illegible]	.116	0.730	25.55	-.372	40.	0.0	1.0
[illegible]	[illegible]	.116	0.730	25.55	-.372	40.	0.0	1.0

```
REACH | QADC      CAA       CAB       CAC          CAD  QADC2          CAE       CAF

 177  | 131.     0.118     0.730     25.[illegible]  -0.372  [illegible]     0.0       1.0
 181    131.     0.118     0.730     25.[illegible]  -0.372  [illegible]     0.0       1.0
 188    398.     0.189     0.866     1529.        -0.048
 190    398.     0.189     0.866     1529.        -0.048
 191    398.     0.189     0.866     1529.        -0.048
 200    398.     0.189     0.866     1529.        -0.048
 201    398.     0.189     0.866     1529.        -0.048
 205    398.     0.189     0.866     1529.        -0.048
 206    122.     0.026     1.662     0.219        0.758  [illegible]   [illegible]  -0.461
 207    122.     0.026     1.662     0.219        0.758  [illegible]   [illegible]  -0.461
 208    122.     0.026     1.662     0.219        0.758  [illegible]   [illegible]  -0.461
 209    122.     0.026     1.662     0.219        0.758  [illegible]   [illegible]  -0.461
 210    122.     0.026     1.662     0.219        0.758  [illegible]   [illegible]  -0.461
 211    122.     0.026     1.662     0.219        0.758  [illegible]   [illegible]  -0.461
 212    122.     0.026     1.662     0.219        0.758  [illegible]   [illegible]  -0.461
 213    122.     0.026     1.662     0.219        0.758  [illegible]   [illegible]  -0.461
 214    122.     0.026     1.662     0.219        0.758  [illegible]   [illegible]  -0.461
 215    398.     0.189     0.866     1529.        -0.048
 216    398.     0.189     0.866     1529.        -0.048
 220    398.     0.189     0.866     1529.        -0.048
 225    398.     0.189     0.866     1529.        -0.048
 226    398.     0.189     0.866     1529.        -0.048
```

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```
REACH    QCRIT      A              B

 226    10000.    0.0846         0.864

 214     5000.    0.453          0.605

 180      800.    0.068          0.952
 180     3150.    1.531          0.486
 180     9000.    5441.         -0.527

 131     2600.    0.064          0.916
 131    10000.    88.0           0.0

  96     1020.    0.0364         0.998
  96     6700.    0.2            0.754
  96    20000.    156.           0.0

  41    10000.    0.113          0.826
```

APPENDIX G

Non-Conservative Water Quality Computations

K-1 Kansas River at Kansas City

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	20	6.6	76	2.2*	.02	106.3	22.1	—
6/20/66	26	7.6	99	5.9*	.24	7.6	5.8	8.6
6/27/66	26	5.8	75	13.1*	—	—	3.8	—
7/04/66	30	0.3	4	2.4*	—	—	3.4	—
7/11/66	30	3.4	47	1.5	.16	5.5	6.1	4.9
7/18/66	29	4.4	60	2.6	.23	6.8	3.2	5.2
7/25/66	28	4.6	61	12.2	.20	15.8	2.3	2.4
8/01/66	27	3.9	51	1.5	.21	7.6	2.7	5.0
8/08/66	27	1.2	16	5.1	.32	10.6	4.7	4.1
8/15/66	25	5.0	63	4.7	.20	6.9	5.2	4.8
8/22/66	25	4.3	54	1.7	.15	6.9	4.5	5.9
8/29/66	25	5.1	65	0.3	.21	4.0	9.5	15.0

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

K-2 Kansas River at Bonner Springs

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	22	6.4	76	3.3*	.38	6.9	25.8	42.8
6/20/66	26	12.7	164	12.7*	.13	17.1	11.2	4.7
6/27/66	25	5.8	73	1.7*	.02	62.5	15.4	—
7/04/66	30	7.7	106	5.8*	.16	16.0	1.8	3.8
7/11/66	29	6.0	82	2.0	—	—	7.9	—
7/18/66	29	8.7	119	4.8	.10	14.4	6.4	2.7
7/25/66	28	5.9	79	4.7	.12	11.1	9.4	5.2
8/01/66	28	6.9	92	5.2	.22	11.6	12.9	4.1
8/08/66	25	8.7	110	5.3	.15	6.9	9.6	5.1
8/15/66	25	8.4	106	5.5	.08	12.2	4.8	2.9
8/22/66	25	8.6	108	3.0	.12	10.0	0.4	4.7
8/29/66	25	7.1	90	0.3	—	—	15.0	—

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

K-2 Kansas River at Bonner Springs

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
9/12/66	24	7.1	87	1.1	.24	3.6	10.0	9.5
9/19/66	18	8.5	93	1.1	.15	5.2	13.7	6.2
10/03/66	19	9.7	108	5.2	.04	24.3	9.2	—
10/17/66	12	10.9	104	2.4	.09	9.7		2.9
10/31/66	10	11.4	105	12.4	.24	10.8		2.7
11/14/66	9	11.5	103	3.0	.02	32.4		—
11/28/66	8	10.9	96	2.8	—	—		—
12/12/66	5	9.6	77	1.8	.09	9.6		1.3
1/09/67	5	13.6	109	0.8	.16	4.6		4.8
1/23/67	9	11.5	102	1.3	.22	4.4		2.9
2/06/67	0	11.9	84	2.3	.10	8.0		2.5
2/20/67	0	14.4	101	6.5	.38	5.5		3.6
3/13/67	9	10.7	96	32.5	.26	20.1		2.5
3/27/67	11	13.7	129	18.6	.20	20.2		2.3
4/10/67	14	8.3	83	1.9	.06	—		—
4/24/67	8	10.4	91	7.8	.23	8.5		1.2
5/01/67	14	10.7	108	30.0	.08	39.3		1.3
5/15/67	14	12.8	129	15.4	.17	15.5		2.4

W-3 Wakarusa at Eudora

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	20	6.1	70	0.6*	.31	6.1	31.8	66.5
6/20/66	26	8.1	105	3.0*	.15	4.8	27.4	10.4
6/27/66	23	4.4	54	0.9*	.09	11.3	61.7	11.6
7/04/66	30	9.5	132	5.2*	.10	11.2	—	2.8
7/11/66	30	4.3	60	0.0	—	—	19.4	—
7/18/66	30	13.4	186	8.6	.08	20.3	22.3	2.4
7/25/66	28	12.1	161	4.0	.19	9.8	16.3	3.1
8/01/66	27	7.2	94	1.0	.25	4.4	—	7.0
8/08/66	27	6.0	79	2.0	.13	6.0	30.0	5.8
8/15/66	25	8.2	104	2.5	.06	12.0	22.8	2.2
8/22/66	24	4.4	55	0.5	.06	8.5	6.0	4.9
8/29/66	25	10.2	129	5.9	.11	18.7	40.0	1.9

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

K-4 Kansas River at Lawrence

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	20	6.1	70	1.2*	.26	6.4	8.2	60.2
6/20/66	27	12.7	167	12.6*	.10	24.0	6.3	2.9
6/27/66	24	5.3	66	0.2*	.05	18.2	23.4	12.8
7/04/66	31	5.8	81	8.1*	.14	14.7	8.0	2.6
7/11/66	30	5.2	72	2.9	.12	9.1	3.4	4.0
7/18/66	32	10.0	141	6.1	.23	14.8	6.3	2.8
7/25/66	31	7.4	103	5.3	.14	13.2	7.3	2.2
8/01/66	29	6.6	90	7.3	.02	48.0	10.0	—
8/08/66	27	5.5	72	3.5	.16	4.3	6.9	7.5
8/15/66	28	9.2	123	6.9	—	—	3.6	—
8/22/66	24	8.1	101	4.5	.17	5.9	4.0	6.8
8/29/66	26	6.7	87	0.5	—	—	10.0	—
9/12/66	24	7.0	88	1.7	.14	6.6	9.8	5.9
9/19/66	19	8.1	91	0.9	—	—	8.3	—
10/03/66	18	9.7	109	5.3	.08	10.6	14.1	4.3

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

K-5 Kansas River at Lecompton

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	20	6.5	75	1.0*	.10	11.3	16.5	30.1
6/20/66	27	8.1	107	4.4*	.19	8.6	12.3	7.0
6/27/66	24	5.6	70	-0.5*	.16	6.8	16.3	34.3
7/04/66	31	10.4	144	9.8*	.07	25.0	—	1.6
7/11/66	31	7.7	107	3.4	.01	57.6	6.9	—
7/18/66	32	10.4	146	4.2	.15	16.0	6.1	2.6
7/25/66	30	8.6	119	5.6	.11	15.4	12.3	2.5
8/01/66	27	7.4	97	2.1	.18	4.1	11.1	9.3
8/08/66	27	7.7	101	2.6	.09	9.7	6.7	5.2
8/15/66	28	9.4	125	4.1	.35	5.3	3.8	7.2
8/22/66	24	7.0	88	0.5	.07	5.0	7.5	7.2
8/29/66	26	7.1	92	0.2	—	—	10.0	—

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

K-5 Kansas River at Lecompton

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
10/17/66	10	9.9	91	2.9	.30	4.9		6.1
10/31/66	11	11.7	110	11.1	.23	12.0		2.5
11/04/66	10	11.0	101	2.6	.13	9.7		3.3
11/28/66	8	11.3	99	3.8	.18	4.1		4.1
12/12/66	6	13.0	108	0.7	.47	4.3		4.0
1/09/67	5	12.7	102	0.6	.23	3.6		6.1
1/23/67	8	12.3	108	1.0	.20	4.5		3.6
2/06/67	0	12.9	91	1.9	.23	4.4		4.1
2/20/67	0	13.1	92	13.2	.31	5.8		4.1
3/13/67	9	12.0	107	18.0	.23	12.8		2.6
3/27/67	11	12.0	113	10.3	.23	9.6		2.9
4/10/67	16	8.2	86	1.6	.05	12.0		3.5
4/24/67	8	11.9	104	7.6	.22	8.4		2.7
5/01/67	15	10.7	110	23.4	.09	27.5		1.4
5/15/67	15	10.7	110	12.4	.25	8.8		4.3

D-6 Delaware River at Perry

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/67	21	7.3	86	1.7*	.18	6.8	7.0	62.5
6/20/66	25	7.5	95	0.8*	.56	2.0	11.3	27.5
6/27/66	23	5.4	67	0.9*	.08	10.6	30.0	21.6
7/04/66	31	13.1	182	2.4*	.03	36.3	—	—
7/11/66	31	6.8	94	0.7	—	—	11.7	—
7/18/66	32	9.5	134	1.3	.21	5.6	5.7	4.1
7/25/66	31	8.2	114	1.7	.15	6.1	15.0	3.1
8/01/66	28	7.9	105	0.6	.34	1.7	14.6	13.5
8/08/66	27	10.0	132	1.7	.25	3.6	6.7	7.2
8/15/66	26	12.9	168	2.1	.34	3.5	11.5	10.3
8/22/66	28	7.7	103	0.7	.06	8.5	7.0	4.8
8/29/66	29	17.6	241	2.0	.09	14.5	—	2.3

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

K-7 Kansas River at Topeka

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	22	7.0	83	11.9*	.08	22.1	9.7	5.7
6/20/66	29	8.6	118	8.2*	.13	12.0	10.6	9.6
6/27/66	26	9.0	116	6.1*	.12	9.1	——	4.4
7/04/66	31	9.3	129	14.0*	.07	37.0	7.7	1.3
7/11/66	31	7.4	103	3.0	.07	19.6	4.1	1.7
7/18/66	33	9.7	139	3.3	.17	13.8	8.3	2.8
7/25/66	30	8.2	114	3.4	.13	11.4	21.7	2.6
8/01/66	27	7.2	95	3.6	.16	7.6	7.3	5.1
8/08/66	27	8.0	105	4.0	.10	4.4	12.5	1.2
8/15/66	28	9.3	124	4.5	.21	15.2	6.9	3.2
8/22/66	24	7.0	88	1.6	.18	5.8	8.2	11.9
8/29/66	27	7.1	93	0.3	.13	6.9	11.4	11.0

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

K-7 Kansas River at Topeka

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
9/12/66	22	7.5	89	1.5	.17	6.7	8.1	7.3
9/19/66	18	8.4	92	1.2	.37	4.0	13.4	6.7
10/03/66	17	9.4	101	4.4	.13	9.6	13.5	3.1
10/17/66	10	10.0	92	1.6	.35	4.4		4.5
10/31/66	11	10.4	98	9.6	.14	13.8		2.5
11/14/66	8	11.7	97	0.7	.22	5.2		4.4
11/28/66	7	12.3	105	2.8	.14	3.6		3.1
12/12/66	6	13.2	110	1.9	.40	2.9		3.4
1/09/67	5	13.9	112	0.5	—	—		—
1/23/67	7	12.6	108	1.5	.06	6.1		2.8
2/06/67	0	13.1	92	1.5	.06	7.2		2.5
2/20/67	0	12.3	87	3.9	.09	7.2		3.2
3/13/67	9	11.5	103	8.2	.18	11.5		2.9
3/27/67	11	11.2	107	10.0	.23	8.8		4.0
4/10/67	15	8.9	92	2.0	.05	19.6		2.0
4/24/67	8	11.8	104	7.2	.21	10.4		2.7
5/01/67	15	9.6	99	6.2	.10	23.2		1.9
5/15/67	15	9.8	100	11.1	.10	15.4		2.2

K-8 Kansas River at Wamego

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	23	6.1	74	9.4*	.17	7.5	25.0	8.7
6/20/66	27	8.7	114	11.7*	.11	12.3	8.0	6.9
6/27/66	27	9.3	122	8.2*	.23	7.1	17.1	5.8
7/04/66	30	11.3	157	23.2*	.17	12.5	—	2.8
7/11/66	30	9.3	129	7.7	.09	11.3	3.8	2.6
7/18/66	26	6.3	82	6.6	.05	18.2	4.4	1.5
7/25/66	26	7.3	95	8.4	.13	7.8	6.7	2.9
8/01/66	26	6.7	87	4.2	.25	8.0	5.6	5.8
8/08/66	27	7.4	97	2.2	.17	5.0	2.5	10.6
8/15/66	30	9.2	128	4.0	.09	13.6	7.1	3.1
8/22/66	24	6.8	85	1.9	.14	8.4	5.3	5.5
8/29/66	27	6.5	86	0.1	.30	4.6	13.4	26.1

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

K-8 Kansas River at Wamego

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
9/12/66	23	7.5	91	0.7	.02	19.6	9.3	1.9
9/19/66	19	8.2	92	0.9	.21	2.8	11.3	6.8
10/03/66	—	9.8	—	1.8	.23	5.6	4.0	4.8
10/17/66	15	9.4	96	0.9	.26	2.0		7.5
10/31/66	12	9.3	89	9.4	.17	5.0		3.0
11/14/66	7	10.7	91	1.0	.20	2.4		1.4
11/28/66	5	11.5	93	1.2	.09	5.6		4.1
12/12/66	0	13.0	92	0.2	.28	1.2		4.3
1/09/67	0	14.7	104	0.4	.23	2.8		7.5
1/23/67	0	11.8	83	1.4	.07	2.5		4.8
2/06/67	0	13.2	93	1.5	.09	7.2		2.4
2/20/67	2	13.7	102	1.4	.11	8.1		2.6
3/13/67	8	13.2	116	8.2	.22	9.6		2.8
3/27/67	10	5.3	49	6.5	—	—		—
4/10/67	12	8.9	86	4.0	.19	7.3		3.8
4/24/67	7	11.4	87	5.6	.06	24.1		1.1
5/01/67	11	10.0	94	10.0	.09	23.2		1.8
5/15/67	12	11.2	108	4.0	.12	13.3		2.9

B-9 Big Blue River at Tuttle Creek

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	22	6.9	82	1.9*	.16	2.1	—	19.0
6/20/66	22	5.8	69	5.8*	.21	2.8	12.4	25.0
6/27/66	23	7.1	85	1.5*	.14	3.6	21.8	4.4
7/04/66	25	7.8	99	3.4*	.14	1.3	—	13.8
7/11/66	28	7.8	104	0.2	.34	0.5	23.1	44.0
7/18/66	24	7.9	99	1.8	.14	3.6	54.0	6.4
7/25/66	24	7.9	99	0.7	.29	2.1	18.5	6.6
8/01/66	27	11.1	146	1.6	.22	6.8	33.3	4.0
8/08/66	25	8.4	106	1.2	.10	5.6	—	4.8
8/15/66	27	9.4	124	1.0	.23	3.2	290.0	6.6
8/22/66	23	7.5	91	0.1	.32	2.1	—	1.9
8/29/66	26	10.2	132	2.1	.24	7.2	11.0	3.8

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

B-9 Big Blue River at Tuttle Creek

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
9/12/66	23	8.3	101	0.2	.19	1.6	22.0	5.0
9/19/66	21	8.3	98	0.1	.28	1.2	32.0	10.0
10/03/66	18	9.1	100	0.2	.44	4.1	21.0	4.9
10/17/66	15	9.1	94	0.9	.39	1.9		8.4
10/31/66	12	9.6	92	0.4	.23	0.8		9.5
11/14/66	8	11.4	100	0.5	.60	0.7		20.0
11/28/66	7	11.5	98	0.4	.17	1.3		7.7
12/12/66	3	12.4	95	0.5	.54	0.6		7.7
1/09/67	1	12.9	93	0.4	.37	0.9		17.8
1/23/67	3	12.4	95	0.4	.19	1.6		8.6
2/06/67	0	13.6	96	0.4	.31	1.7		9.6
2/20/67	2	14.5	108	1.7	.20	4.1		5.4
3/13/67	6	10.8	90	0.8	.15	3.9		5.1
3/27/67	10	9.4	86	0.9	.07	7.5		3.7
4/10/67	13	9.4	92	2.7	.23	6.5		3.7
4/24/67	11	9.7	92	1.2	.23	3.2		0.5
5/01/67	13	8.5	83	3.1	.20	4.1		5.8
5/15/67	13	9.4	92	1.2	.16	2.1		6.7

K-10 Kansas River at Manhattan

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	24	7.5	94	11.2*	—	—	22.7	—
6/20/66	26	7.5	98	10.6*	.26	7.6	8.0	10.5
6/27/66	27	8.5	112	6.5*	.14	7.5	5.0	4.8
7/04/66	33	8.3	119	16.2*	.19	11.0	9.1	3.9
7/11/66	32	8.0	113	4.4	.15	8.7	2.5	3.9
7/18/66	27	7.8	103	5.6	.12	9.3	3.7	3.1
7/25/66	26	7.5	108	7.6	.12	10.0	4.6	2.8
8/01/66	27	6.6	87	2.6	.29	7.8	9.3	6.5
8/08/66	26	7.5	97	2.1	.10	11.2	16.3	4.6
8/15/66	29	8.2	112	3.3	.14	8.4	10.7	3.8
8/22/66	22	7.4	88	1.9	.20	4.4	6.5	8.2
8/29/66	26	6.8	88	0.5	.25	3.2	12.2	28.1
9/12/66	24	7.6	95	1.4	.10	4.8	7.0	11.9
9/19/66	18	8.5	93	8.3	.12	8.2	7.0	5.4
10/03/66	17	10.9	117	10.7	.24	13.2	6.8	3.1

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

R-11 Republican River Below Milford

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	25	7.7	97	7.5*	.09	5.6	13.0	8.9
6/20/66	22	6.3	75	13.1*	.14	7.5	4.3	10.7
6/27/66	24	4.4	55	10.5*	.18	7.4	2.0	4.6
7/04/66	30	6.9	96	6.8*	.20	2.4	7.8	12.1
7/11/66	31	7.3	101	3.8	.26	2.4	3.0	11.7
7/18/66	28	7.6	101	9.9	—	—	5.4	—
7/25/66	28	7.9	105	6.8	.19	6.9	5.1	3.5
8/01/66	29	7.1	97	1.7	.31	4.2	10.2	8.1
8/08/66	27	7.8	103	3.1	.16	6.8	—	5.3
8/15/66	25	7.3	92	3.4	.13	7.8	5.8	4.6
8/22/66	22	7.1	85	2.9	.19	4.9	9.0	8.6
8/29/66	24	7.7	96	1.5	.07	9.6	10.9	4.0

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

R-11 Republican River Below Milford

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
9/12/66	23	7.7	94	3.3	.09	5.6	20.0	5.4
9/19/66	19	9.0	101	4.7	.11	6.5	8.3	5.2
10/03/66	14	10.0	101	7.6	.25	9.2	5.4	5.1
10/17/66	10	9.9	110	4.9	.25	4.4		4.3
10/31/66	8	11.4	100	6.6	.19	5.3		2.5
11/14/66	4	12.7	100	0.4	.60	0.7		20.0
11/28/66	18	9.0	99	4.2	.09	7.2		2.6
12/12/66	1	13.1	95	1.2	.14	3.6		3.6
1/09/67	3	15.0	115	0.3	.07	2.5		5.6
1/23/67	5	13.9	112	0.3	.31	1.6		7.5
2/06/67	0	15.1	106	0.3	.23	2.0		7.0
2/20/67	2	12.9	96	2.8	.30	4.4		5.0
3/13/67	5	12.0	97	1.1	.28	2.45		9.0
3/27/67	12	11.0	106	0.9	.12	3.3		5.4
4/10/67	16	9.5	100	0.4	.29	1.95		10.3
4/24/67	13	11.7	115	0.2	.14	0.9		1.1
5/01/67	10	11.4	105	0.1	.17	1.3		10.8
5/15/67	14	13.8	139	0.2	.10	1.6		10.0

SH 12 Smoky Hill River at Junction City

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	24	6.4	80	9.5*	.10	11.2	25.8	5.8
6/20/66	22	6.9	82	4.3*	.17	3.8	9.1	21.1
6/27/66	24	4.4	55	12.7*	.23	3.6	14.7	8.1
7/04/66	29	6.9	95	7.9*	.09	11.3	2	3.1
7/11/66	32	7.5	106	2.3	—	—	14.0	—
7/18/66	30	6.9	96	4.7	.20	5.2	45.0	5.4
7/25/66	28	7.6	101	6.0	.17	7.9	17.5	2.9
8/01/66	28	5.8	77	2.0	.38	5.0	9.5	10.4
8/08/66	27	6.4	84	0.8	.09	16.9	17.3	3.3
8/15/66	25	7.0	89	1.2	.06	8.5	18.9	3.6
8/22/66	23	7.2	88	2.5	.09	5.6	9.0	6.4
8/29/66	23	6.8	83	-0.5	—	—	16.7	—

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

SH 13 Smoky Hill River at Enterprise

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	26	5.6	73	6.4*	—	—	17.4	—
6/20/66	23	7.3	89	3.9*	.14	4.5	11.6	20.0
6/27/66	27	9.7	128	12.5*	.09	7.2	7.1	3.9
7/04/66	29	6.4	88	14.5*	.11	9.8	13.0	3.0
7/11/66	32	11.3	159	2.0	.13	9.6	22.9	4.0
7/18/66	32	9.9	139	8.6	.26	8.9	8.2	3.6
7/25/66	28	6.4	85	12.0	.13	9.6	4.7	2.9
8/01/66	30	5.4	75	0.8	.30	7.9	10.0	10.6
8/08/66	26	6.5	84	1.3	.10	7.2	14.3	5.8
8/15/66	24	6.3	79	1.3	.16	3.4	6.5	9.7
8/22/66	22	5.0	60	0.0	.11	11.4	17.0	31.5
8/29/66	23	6.7	82	0.1	.19	4.9	19.6	19.0

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

SH 13 Smoky Hill River at Enterprise

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
10/17/66	15	9.3	96	4.5	.16	5.5		5.6
10/31/66	12	9.8	94	5.2	.11	6.5		2.6
11/14/66	9	13.1	117	2.8	.25	3.2		4.4
11/28/66	6	11.0	92	1.9	.32	2.1		11.9
12/12/66	0	13.8	97	0.2	.14	1.8		3.6
1/09/67	0	15.4	108	0.1	.14	1.8		8.9
1/23/67	4	15.1	119	0.3	—	—		—
2/06/67	0	12.0	85	0.5	.07	2.5		5.2
2/20/67	2	14.0	104	6.3	.10	5.6		2.7
3/13/67	9	11.0	98	14.6	.23	8.8		2.7
3/27/67	15	10.3	106	10.4	.17	11.8		2.8
4/10/67	16	7.9	83	5.2	.20	8.1		4.4
4/24/67	13	8.9	87	8.8	.17	9.1		2.8
5/01/67	15	9.5	98	10.7	.24	8.4		4.5
5/15/67	14	10.3	104	9.6	.24	11.2		3.4

SH 14 Smoky Hill River at New Cambria

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	27	6.8	91	6.1*	.09	5.7	8.8	13.2
6/20/66	27	7.2	96	0.1*	—	—	80.0	—
6/27/66	25	7.9	101	—	—	—	4.9	—
7/04/66	31	14.7	207	18.4*	.19	13.1	4.1	2.4
7/11/66	31	17.1	241	9.2	.11	17.2	2.0	2.0
7/18/66	28	10.4	142	10.2	.15	10.3	2.4	3.4
7/25/66	28	5.2	71	2.1	.20	4.8	4.1	7.7
8/01/66	29	6.0	83	0.7	.27	6.1	23.1	7.4
8/08/66	26	6.8	89	1.3	.34	3.5	14.4	7.1
8/15/66	26	6.5	86	1.7	.12	7.6	7.1	4.3
8/22/66	22	4.4	53	0.0	.30	4.6	11.0	47.2
8/29/66	25	6.8	87	2.2	.37	4.5	20.6	5.8

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

SA 15 Saline River at New Cambria

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	27	6.6	88	10.6*	.22	7.6	—	9.9
6/20/66	27	6.0	80	10.3*	.29	7.8	15.3	6.4
6/27/66	25	3.6	46	17.8*	.13	9.6	—	4.0
7/04/66	30	4.6	65	10.7*	.05	25.9	25.0	1.4
7/11/66	30	5.7	80	7.2	.20	8.9	10.6	4.2
7/18/66	28	3.2	43	6.0	.10	9.6	22.0	3.9
7/25/66	27	4.5	60	1.3	.06	10.8	10.0	4.0
8/01/66	29	4.5	63	6.7	.23	9.2	12.5	4.7
8/08/66	26	4.8	63	6.6	.22	8.0	18.5	4.3
8/15/66	26	5.3	70	6.2	.08	10.6	34.3	3.3
8/22/66	21	4.4	52	0.0	.28	5.7	11.3	51.4
8/29/66	25	5.9	76	1.1	.14	8.4	20.5	5.7

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

SO 16 Solomon River at Niles

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	26	5.1	67	12.1*	.18	7.0	12.9	11.4
6/20/66	24	5.9	75	13.5*	.15	10.0	6.2	4.0
6/27/66	28	8.0	110	10.1*	.21	7.6	11.6	4.3
7/04/66	28	6.0	82	17.6*	.13	6.0	12.6	5.5
7/11/66	32	7.3	104	4.2	.18	8.3	5.6	3.6
7/18/66	30	7.7	108	4.3	.12	17.8	9.0	2.1
7/25/66	30	7.7	108	2.3	.19	5.6	8.4	2.1
8/01/66	29	5.3	74	0.4	.29	10.3	13.3	10.4
8/08/66	29	5.6	78	6.4	.21	13.3	18.9	8.9
8/15/66	25	7.4	95	4.6	.16	6.8	21.0	3.2
8/22/66	22	6.6	80	0.0	.21	7.6	18.0	3.5
8/29/66	21	4.0	48	0.1	.06	10.8	23.5	41.1

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

SC 17 Salt Creek at Minneapolis

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	25	6.3	81	27.2*	.14	13.5	59.0	6.7
6/20/66	30	8.6	121	26.3*	.12	18.7	15.6	1.1
6/27/66	28	12.5	171	25.6*	.06	48.0	44.3	1.6
7/04/66	25	3.1	40	36.3*	.12	33.3	5.0	2.2
7/11/66	29	5.6	78	19.0	.20	24.2	11.0	3.4
7/18/66	29	6.8	94	24.3	.14	36.0	43.3	2.8
7/25/66	27	2.7	36	7.9	.14	9.3	7.8	5.3
8/01/66	28	2.0	27	1.4	.37	9.0	16.3	6.9
8/08/66	21	3.7	44	10.3	.24	9.2	13.8	4.5
8/15/66	26	3.9	51	6.1	.05	24.1	44.0	1.8
8/22/66	20	5.3	62	0.0	.41	4.8	8.3	30.2
8/29/66	23	4.0	49	6.5	.03	50.7	13.3	0.9

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

SO 18 Solomon River at Glen Elder

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	26	6.6	87	14.7*	.04	22.5	22.6	3.3
6/20/66	28	8.8	121	23.9*	.20	6.9	9.3	10.0
6/27/66	24	6.1	77	8.0*	.06	15.6	8.9	14.4
7/04/66	24	4.8	61	16.9*	.21	6.8	7.1	4.1
7/11/66	28	6.0	82	1.4	.23	5.6	6.1	21.8
7/18/66	28	7.1	97	6.7	.19	7.3	8.2	3.3
7/25/66	26	7.0	92	15.5	.19	11.0	10.0	3.3
8/01/66	27	6.0	80	2.6	.29	7.0	11.4	7.1
8/08/66	20	7.5	87	6.0	.10	17.6	19.1	1.9
8/15/66	24	7.6	96	11.3	.10	12.0	25.0	2.8
8/22/66	20	5.2	60	0.2	.09	12.9	11.3	12.3
8/29/66	22	6.9	84	7.1	.12	5.4	15.0	5.2

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

SO 18 Solomon River at Glen Elder

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
9/12/66	21	7.6	90	20.0*	—	—	24.1	—
9/19/66	18	9.1	102	1.7	.29	4.5	15.0	5.8
10/03/66	15	7.9	83	1.7	.47	3.8	16.0	4.5
10/17/66	7	9.5	82	1.7	.35	4.0		4.3
10/31/66	9	8.4	76	1.4	.38	4.1		3.7
11/14/66	4	10.7	86	0.2	.15	3.0		8.0
11/28/66	1	11.7	86	0.1	.26	2.0		6.5
12/12/66	0	12.0	86	0.2	.34	2.2		4.0
1/09/67	0	5.1	37	0.1	.23	2.0		8.5
1/23/67	1	8.3	61	2.4	.04	6.4		8.7
2/06/67	—	12.7	—	0.2	.11	4.0		3.0
2/20/67	0	12.7	91	0.1	.37	2.3		7.1
3/13/67	7	9.8	84	0.6	.54	5.7		2.4
3/27/67	10	8.5	79	2.5	.43	4.0		5.0
4/10/67	11	8.8	84	16.0	.22	12.3		2.1
4/24/67	5	11.1	91	6.3	.35	4.0		3.2
5/01/67	11	7.9	75	8.0	.23	5.2		4.8
5/15/67	12	8.9	87	26.3	.22	9.2		3.4

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

SA 19 Saline River at Tescott

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	27	3.9	52	10.8*	.38	8.3	—	7.2
6/20/66	27	7.7	103	23.5*	.37	18.0	—	3.9
6/27/66	27	3.4	45	16.9*	.06	18.0	22.0	2.4
7/04/66	29	4.7	65	23.4*	.25	18.1	22.5	3.0
7/11/66	28	4.7	64	6.1	.30	14.5	23.8	3.2
7/18/66	28	4.4	60	4.5	.25	14.1	2.5	3.1
7/25/66	29	4.1	60	4.7	.20	12.1	10.8	3.6
8/01/66	29	3.8	53	7.6	.32	10.6	57.5	3.9
8/08/66	24	5.6	71	8.1	.24	15.6	14.4	3.0
8/15/66	24	5.1	65	2.5	.17	6.6	7.7	5.3
8/22/66	21	5.7	68	0.0	.26	7.6	9.5	24.9
8/29/66	24	5.2	66	1.5	.22	5.6	19.6	5.5

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

SA 20 Saline River at Sylvan Grove

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	26	8.8	121	11.7*	.12	9.3	95.0	8.6
6/20/66	25	6.8	87	11.5*	.29	7.0	40.0	6.4
6/27/66	23	3.8	47	13.4*	.17	7.9	190.0	4.6
7/04/66	27	5.9	79	17.9*	.09	11.2	——	3.0
7/11/66	27	8.0	107	2.5	.12	15.1	24.3	2.2
7/18/66	28	3.8	52	2.1	.26	6.4	——	3.3
7/25/66	27	3.5	47	2.4	.23	4.4	18.5	5.5
8/01/66	28	4.0	55	2.8	.17	9.6	57.5	3.0
8/08/66	28	5.6	77	0.2	——	——	20.0	——
8/15/66	24	5.2	66	1.2	.38	4.1	17.7	8.0
8/22/66	21	5.0	60	0.0	——	——	44.0	15.6
8/29/66	23	5.8	72	3.5	.34	4.7	——	5.3

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

SA 20 Saline River at Sylvan Grove

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
9/12/66	21	6.3	75	9.7*	.21	6.0	55.0	5.7
9/19/66	18	8.6	97	2.0	.40	4.7	22.0	5.5
10/03/66	16	7.1	75	3.2	.43	4.0	40.0	6.0
10/17/66	8	9.5	84	0.7	.43	2.5		7.2
10/31/66	9	7.6	69	2.8	.42	4.9		4.7
11/14/66	4	9.6	77	1.0	.30	5.8		6.2
11/28/66	1	11.5	85	2.5	.23	4.8		5.8
12/12/66	0	12.2	88	0.4	.14	4.5		3.8
1/09/67	0	8.5	61	0.1	.27	1.7		15.0
1/23/67	1	9.1	67	0.0	.43	2.5		5.6
2/06/67	—	11.8	—	0.0	.26	2.4		7.9
2/20/67	-1	11.9	86	0.2	.18	2.9		7.9
3/13/67	8	7.7	68	5.5	.13	6.0		3.5
3/27/67	11	6.4	61	10.7	.16	9.4		4.0
4/10/67	12	6.8	67	14.4	.06	30.0		1.3
4/24/67	5	9.5	78	5.2	.41	8.7		3.0
5/01/67	12	3.9	38	9.6	.16	9.4		4.6
6/15/67	11	5.9	66	7.7	.21	6.0		5.5

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

SH 21 Smoky Hill River at Mentor

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	24	6.9	88	4.6*	.10	7.2	—	8.3
6/20/66	23	7.0	87	1.9*	.29	7.0	—	6.4
6/27/66	25	6.8	87	5.7*	.15	7.3	—	3.4
7/04/66	26	6.3	83	6.5*	.09	13.7	—	1.5
7/11/66	26	6.9	91	1.3	.15	5.2	15.6	4.6
7/18/66	27	6.3	84	2.0	.24	5.6	16.7	4.5
7/25/66	27	6.6	88	0.9	.14	4.5	20.8	5.8
8/01/66	28	6.1	84	0.3	.35	5.3	70.0	6.0
8/08/66	26	6.8	89	0.4	.42	3.9	31.1	6.7
8/15/66	26	6.8	89	0.0	.31	3.8	9.4	14.0
8/22/66	23	7.2	89	0.0	.35	3.1	36.0	8.1
8/29/66	24	7.4	94	1.2	—	—	—	—

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

SH 22 Smoky Hill River at Langley

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
9/12/66	23	8.0	99	0.7*	.14	2.7	26.0	4.8
9/19/66	21	8.8	105	0.2	.31	3.3	17.5	4.8
10/03/66	17	8.4	92	0.3	.32	2.9	18.0	5.9
10/17/66	14	9.6	98	0.0	.37	2.3		11.3
10/31/66	11	8.5	81	1.2	.28	2.8		16.8
11/14/66	7	9.6	83	0.5	.20	2.4		6.3
11/28/66	4	10.1	81	0.7	.37	3.2		4.4
12/12/66	2	11.4	86	0.5	.19	3.3		3.5
1/09/67	1	11.8	87	0.3	.28	2.5		4.7
1/23/67	1	11.1	82	0.4	.43	2.3		4.6
2/06/67	—	11.8	—	1.2	—	—		—
2/20/67	0	11.6	83	0.7	.58	2.1		5.5
3/13/67	6	10.6	89	1.0	.29	3.3		3.5
3/27/67	9	9.4	85	1.8	.18	5.8		2.4
4/10/67	14	8.1	83	1.3	.17	2.5		7.2
4/24/67	11	9.6	91	0.4	.32	2.1		5.7
5/01/67	11	9.0	86	0.9	.33	3.8		5.2
5/15/67	12	8.3	81	0.4	.21	2.8		5.0

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

SH 22 Smoky Hill River at Langley

Date	Temperature °C	Observed Dissolved Oxygen mg/L	Percent Saturation	24 - Hour Oxygen Production mg/L	K_1 Base e /Day	L_1 mg/L	NO_3/PO_4	COD/L_1
6/13/66	23	8.4	104	1.1*	.34	2.2	—	9.1
6/20/66	25	8.0	103	0.9*	.51	1.8	—	8.3
6/27/66	23	7.7	95	3.0*	.42	3.9	—	4.9
7/04/66	24	8.1	103	0.9*	.34	4.7	—	3.2
7/11/66	26	8.1	107	0.1	.19	3.3	25.0	4.0
7/18/66	28	7.1	97	0.4	—	—	25.4	—
7/25/66	27	7.1	95	0.4	.51	1.8	85.0	8.3
8/01/66	27	7.1	95	0.0	.43	3.0	70.0	5.0
8/08/66	26	7.4	97	0.6	.25	3.2	25.4	4.7
8/15/66	24	7.4	4	0.4	.46	2.1	31.8	9.5
8/22/66	24	7.6	96	0.4	.26	2.4	36.0	5.8
8/29/66	24	8.0	01	0.3	.21	2.8	45.0	5.0

* Designates photosynthetic oxygen production after 72 hours of continuous illumination

APPENDIX H

Fixed Vector Used in the Modified Dynamic Conservative Model

FIXED VECTOR

```
NR1 NR2  L     HA      HB    VA      VB     DAA     DAB    IS1 IS2                I

  4  5 16.0  0.159  0.4540.133  0.426  .262     0.       3  1 0.272                3
  1  1 11.0  2.     0.0   1.0   0.0    .184     0.0      3  1 0.271                4
  7  1  5.0  0.159  0.384 .133  0.328  .058     0.0      3  1 0.272                5
 11  1 10.0  0.159  0.384 .133  0.328  .2676    0.       3  2 0.355                7
 15  2  3.0  0.139  0.384 .133  0.328 0.1361    0.       3  2 0.355               10
 16  1 17.0  0.43   0.302 .5    0.168 0.3637    0.       2  1 0.361               15
  1  1  0.   0.43   0.302 .5    0.168 1.0       0.       2  1 0.361               16
 25 29  7.   0.139  0.384 .133  0.328  .143     7.0      3  2 0.355               20
 26  1 13.   0.35   0.438 .55   0.19   .2686    0.0      3  1 0.371               25
  1  1  4.0  0.35   0.438 .55   0.19  1.        0.0      3  1 0.371               26
 30  1 14.0  0.139  0.384 .133  0.328  .1460   10.0      3  2 0.355               29
 36  1 13.   0.13   0.640 .364  0.21  0.1361   18.0      1  2 0.352               30
  4 45  1.0  0.13   0.640 .364  0.21  1.0       0.       1  1 0.274               35
 41  1 31.0  0.1    0.5   .55   0.27  0.384     0.       3  1 0.423               40
  1  1  0.0  0.1    0.5   .55   0.27  1.        0.       3  1 0.423               41
 51 55 17.0  0.13   0.640 .364  0.21  0.3 1     0.       3  6 0.274               45
 51  1  7.   0.22   0.457 .67   0.206  .146     0.       6  1 0.267               50
  1  1  0.0  0.22   0.457 .67   0.206 1.        0.       6  1 0.267               51
 58  1  2.0  0.154  0.450 .163  0.306 1.        0.       1  1 0.274               55
 59  1  4.0  0.154  0.450 .163  0.306 0.461     0.0      6  1 0.274               56
 60 64 14.1  0.154  0.450 .163  0.306 0.766     0.0      6  1 0.423               59
 61  1 16.0  0.15   0.469 .45   0.285  .291     0.0      8  1 0.794               60
  1  1  0.0  0.15   0.469 .45   0.285 1.0       0.0      8  1 0.794               61
 65  1  6.0  0.154  0.450 .163  0.306 0.134     0.0      4  1 0.423               64
  7 85 14.0  0.154  0.450 .163  0.306  .335     0.0      6  1 0.423               65
 75  8 18.0  0.22   0.485 .74   0.162 0.335     0.0     10  1 0.491               70
 76  1 10.   0.25   0.476 .66   0.206  .436     0.0      9  1 0.491               75
  1  1  0.0  0.25   0.476 .66   0.206 1.0       0.0      9  1 0.491               76
 81  1 10.0  0.22   0.4850.74   0.162 0.337     0.0     10  1 0.491               80
  1  1  0.0  0.22   0.4850.74   0.162 1.0       0.      10  1 0.491               81
```

```
HR1 HR2  L     HA      HB    VA      VB     QA1      QAB     IG1 IG2   S            I

 90   1  8.0   0. 55  0.490 .333   0.239   [illegible]  0.[illegible]   8  1  .423     85
 95115 16.0   0.55   0.490 .333   0.239   0.440    0.[illegible]   8  1  0.477    90
 96   1  7.3   0. 78  0.55  0.2[illegible]   0.276   .13[illegible]     0.[illegible]   6  1  0.540    95
  1   1  0.0   0. 78  0.55  0.29   0.276   1.[illegible]      0.[illegible]  12  1  0.540    96
120120 18.5   0.12   0.42  0.27   0.284   0.784    [illegible]      9  1  0.477   115
121   1 14.6   0.122  0.5[illegible] 0.37   0.30    0.218    0.      15  1  0.305   120
  1   1  [illegible]  0.123  0.5[illegible] 0.37   0.30    1.[illegible]       0.[illegible]    15  1  .305    12[illegible]
129135  [illegible]  0.12   0.42  0.27[illegible]  0.284   .1[illegible]      0.[illegible]    15  1  .477    12[illegible]
130   1 11.1   0. [illegible]  0.5[illegible]  .3[illegible]   0.265   .274     0.      17  1  0.545   [illegible]
131   1  7.5   0.[illegible]   0.[illegible]  .38[illegible]  0.234   .167     0.      1[illegible]  1  0.545   [illegible]
  1   1  0.0   0.[illegible]   0.6[illegible] .38[illegible]  0.234   1.[illegible]       0.      1[illegible]  1  0.5[illegible]   [illegible]
140148  [illegible]  0.226  0.424 .363   0.30    .1[illegible]      0.      17  1  .236    [illegible]
141   1   [illegible]   .22   0.49[illegible] .43    0.254   .23[illegible]     .       17  1  .7[illegible]     14[illegible]
142   1 2[illegible]   .22    0.4[illegible]  .43    0.254   .417     0.      1[illegible]  1  .7[illegible]     14[illegible]
  1   1  [illegible]   .22    0.4[illegible]  .43    0.254   .5[illegible]      .       17  1  .7[illegible]     14[illegible]
15[illegible]154 14.[illegible]  .2[illegible]    0.42[illegible] .36[illegible]  0.5[illegible]    .2[illegible]      .       1[illegible]  1  .23[illegible]    14[illegible]
151   1  [illegible]   .2[illegible]    0.4[illegible]  .21    0.26    .1[illegible]      .       1[illegible]  1  .2[illegible]     15[illegible]
  1   1  0.0   .2[illegible]    0.4[illegible]  .21    0.2[illegible]    1.[illegible]       .       1[illegible]  1  .[illegible]      15[illegible]
155   1 18.4   .2[illegible]    0.4[illegible]  .361   .5[illegible]     .1[illegible]      .       17 18  .23[illegible]    15[illegible]
160162 10.[illegible]  .226   0.424 .363   .5[illegible]      .147    0.[illegible]    1[illegible]  1  .2[illegible]     1[illegible]
161   1 12.[illegible]  .47    0.4[illegible]  .5[illegible]    .143      .16[illegible]    .       [illegible]  1  .5[illegible]     16[illegible]
  1   1  [illegible]   .47    0.4[illegible]  .5[illegible]    .14[illegible]      .[illegible]       .       [illegible]  1  .5[illegible]     1[illegible]
17[illegible]1[illegible] 15.[illegible]  .2[illegible]    0.42[illegible] .36[illegible]  .5[illegible]      1.[illegible]      .       1[illegible]  1  .2[illegible]     1[illegible]
171   1 15.[illegible]  0.16   0.434 .3[illegible]   0.227     .28[illegible]    0.[illegible]    1[illegible]  1  .3[illegible]     1[illegible]
172174 33.[illegible]  0.16   0.[illegible]4 .30    0.227     .2[illegible]     0.[illegible]    1[illegible]  1  .32[illegible]    1[illegible]
174   1 10.[illegible]  0.31   0.44[illegible] .3[illegible]   0.26[illegible]    0.16[illegible]   0.[illegible]    2[illegible]  1  .4[illegible]     1[illegible]
  1   1  [illegible]   0.31   0.44[illegible] .3[illegible]   0.26[illegible]    1.[illegible]      0.[illegible]    2[illegible]  1  .5[illegible]     17[illegible]
175   1 1[illegible]   0.16   0.54[illegible] .3[illegible]   0.227     .16[illegible]   0.      1[illegible]  1  0.3[illegible]    174
176   1 26.[illegible]  .16    0.524 .3[illegible]   0.227     .[illegible]       .       1[illegible]  1  0.3[illegible]    17[illegible]
177   1 10.[illegible]  0.16   0.512 .36    0.265     .2[illegible]     .       1[illegible]  1  .3[illegible]     17[illegible]
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CRES LABORATORIES

Chemical Engineering Low Temperature Laboratory

Remote Sensing Laboratory

Electronics Research Laboratory

Chemical Engineering Heat Transfer Laboratory

Nuclear Engineering Laboratory

Environmental Health Engineering Laboratory

Digital Computer Technology Laboratory

Water Resources Institute